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MODEL EFFECTIVENESS AS A FUNCTION OF PERSONNEL

$$\left[ME = f(PER)\right]$$

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Although human participation and influence are pervasive in actual combat, the effects of human factors or human performance are frequently considered only implicitly, if at all in combat models. The need for better representation of the human element in combat models has frequently been identified during the past 30 years. However, the majority of the current analytic combat models provide a better representation of equipment capabilities than they do of the human component of weapon systems.

The purpose of this project is to identify those areas in which the modeling of battlefield processes in the Concepts Analysis Agency could and should be modified to include the effects of human factors and human performance.

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This project demonstrated that human data can make large differences in combat results and that the Force Evaluation Model (FORCEM) could be modified to reflect the detrimental effects of environment and stress on humans. This project also showed that preprocessing and sensitivity testing could be used to evaluate the effects of soldier characteristics such as mental category that do not change appreciably during the combat period. The results of this project include a list of human data that should be included in combat models, an implementation plan for the list, and another list of important variables that may need more study before they can be incorporated. Sufficient human performance data does exist to develop a data base that includes both equipment and human data for parameters such as probability of detection and probability of hit. One additional benefit from this study is development of a common vocabulary for use of human data in combat models. This vocabulary will be used for communication between the modeling community and the behavioral and human factor research community.

MODEL EFFECTIVENESS AS A FUNCTION OF PERSONNEL

(ME = f(PER))

September 1986

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SUBJECT: Model Effectiveness as a Function of Personnel Study (ME=f(PER))

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1. Reference:

    a. CAA Memo 600-2, 10 June 1985, Research and Study Fellowships.

    b. Study proposal, Sally J. Van Nostrand, 8 July 1985, subject:
Application for CAA Research and Study Fellowship.

2. This is the final report of the ME=f(PER) study which was approved as a CAA
Research and Study Fellowship project. The study evaluated CAA combat models
and human factors to determine whether human performance factors should be
included in the combat models. This report summarizes the human data that are
available, demonstrates differences in model output that are caused by human
data, and discusses additional human data that are needed for combat models.
An implementation plan for recommended model changes is included at Appendix G.

3. The author expresses appreciation to all commands and agencies which have
contributed to this product with particular appreciation to Dr. Irving Alderman,
U.S. Army Research Institute. Inquiries should be directed to the Chief,
Personnel Systems Analysis Division (ATTN: CSCA-FSP), Force Systems
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                                    SALLY J. VAN NOSTRAND
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	MODEL EFFECTIVENESS AS A FUNCTION OF PERSONNEL [ME = f(PER)]	STUDY SUMMARY
CAA		CAA-SR-86-34

THE REASON FOR PERFORMING THIS STUDY is to identify those areas in which the modeling of battlefield processes in the US Army Concepts Analysis Agency (CAA) could and should be modified to include the effects of human factors or human performance.

THE PRINCIPAL ACCOMPLISHMENTS of the work reported here are:

(1) This research determined that humans make large differences in real-world combat results. Therefore, human data should make similar differences in the results of models of combat. A modification of the Force Evaluation Model (FORCEM) which reflects the detrimental effects of environment and stress on humans was created. This modification was used to demonstrate model results that could be expected when human data are represented.

(2) It was determined that the human performance data that are available were collected for other purposes (e.g., for operational testing or for training evaluation) and that these data must be obtained from multiple sources. A complete set of all data that might be useful for modeling purposes cannot be generated from extant data. However, the physical and psychological limits of human performance indicate that the results of combat are as likely to be determined by human performance under stress, such as that generated by continuous operations, as by differences in equipment capabilities. Therefore, there is an urgent need for additional human performance data.

(3) This project demonstrated that preprocessing and sensitivity testing could be used to evaluate the effects of soldier characteristics, such as mental category, that do not change appreciably during the combat period.

(4) The results of this project include a list of human data that should be included in combat models, an implementation plan for this list, and another list of important variables that may need more study before they can be incorporated.

(5) An additional benefit from this research is the development of a common vocabulary for use of human data in combat models. This vocabulary will be used for communication between the modeling community and the human research community.

THE KEY ASSUMPTIONS

(1) Enough verifiable data exist which can be used as a basis for testing the concept of modeling human performance in combat.

(2) Algorithms can be developed to model human factors.

(3) These algorithms can be adapted to the CAA combat models.

THE PRINCIPAL LIMITATION is that resources available for this study do not permit making and testing modifications to model code or developing a human factor data base.

THE STUDY OBJECTIVES are to:

(1) Identify the combat processes which are potentially most sensitive to the effects of human factors or human performance.

(2) Determine existing data base elements and process algorithms which will permit appropriate modifications of the models of combat processes by simple changes to the data base.

(3) Define and verify new algorithms and data that are necessary to generate the additional human factor functions that should be included in the combat model processes.

THE BASIC APPROACH is that both a search for human data relevant to combat results and a model ahalysis of appropriate points for inclusion of human data are used. The model analysis is not constrained by whether data are already available for use, nor is the search for data limited to that which would be immediately usable in the model.

THE STUDY EFFORT was performed by Ms Sally J. Van Nostrand under the CAA Research and Study Fellowship Program.

COMMENTS AND QUESTIONS may be addressed to the Director, US Army Concepts Analysis Agency, ATTN: CSCA-FSP, 8120 Woodmont Avenue, Bethesda, MD 20814-2797.

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MODEL EFFECTIVENESS AS A FUNCTION OF PERSONNEL

[ME = f(PER)]

EXECUTIVE SUMMARY

1. PROBLEM. Although the need for better representation of the human element in combat models has frequently been identified during the past 30 years, most analytic combat models neglect human capabilities.

2. BACKGROUND. Models created for evaluating and comparing individual weapon systems are usually considered the origins of combat models. When the equipments are similar and it can be assumed that the same crews would operate each of the systems being compared, then differences in human performance may produce negligible differences in model outcomes. National differences and differences in tactics and doctrine affect soldier performance. Therefore, when the modeler compares a weapon system for the Blue side against a weapon system for the Red side, the assumption that crews make no differences is much less valid. The importance of the soldier and crew to combat outcomes has long been recognized by military leaders. Yet, many of our present combat models assume that all human tasks are performed perfectly. Models of processes in which humans are important to the real world outcomes (such as combat) may contain gross errors when they contain data on equipment performance and ignore human performance.

3. PURPOSE. The purpose of this project is to identify those areas in which the modeling of battlefield processes in the Concepts Analysis Agency could and should be modified to include the effects of human factors and human performance.

4. SCOPE

    a. The first focus of this research is human factor information that would be suitable for inclusion in the CAA combat models.

    b. The other focus is on the combat models in order to determine which is most suitable for inclusion of human data.

5. LIMITATION. With the limited resources of a fellowship project, combat model changes cannot be made, nor can a human data base be created. However, one of the products of this research is an implementation plan for making recommended enhancements to the combat models.

6. APPROACH AND METHODOLOGY. Two concurrent approaches are used in this research. As depicted in Figure 1, the model analysis is not constrained by whether data is already available for use, nor is the data search limited to that which could be immediately used in the model. It is important to identify human variables which can determine combat results so that those human variables can also determine the results in future combat models. In the interim, present models should be analyzed to determine whether it is feasible to modify them to include the human variables. The identification of human data that the models need, but for which no data source has been identified, defines a priority need for human performance research.
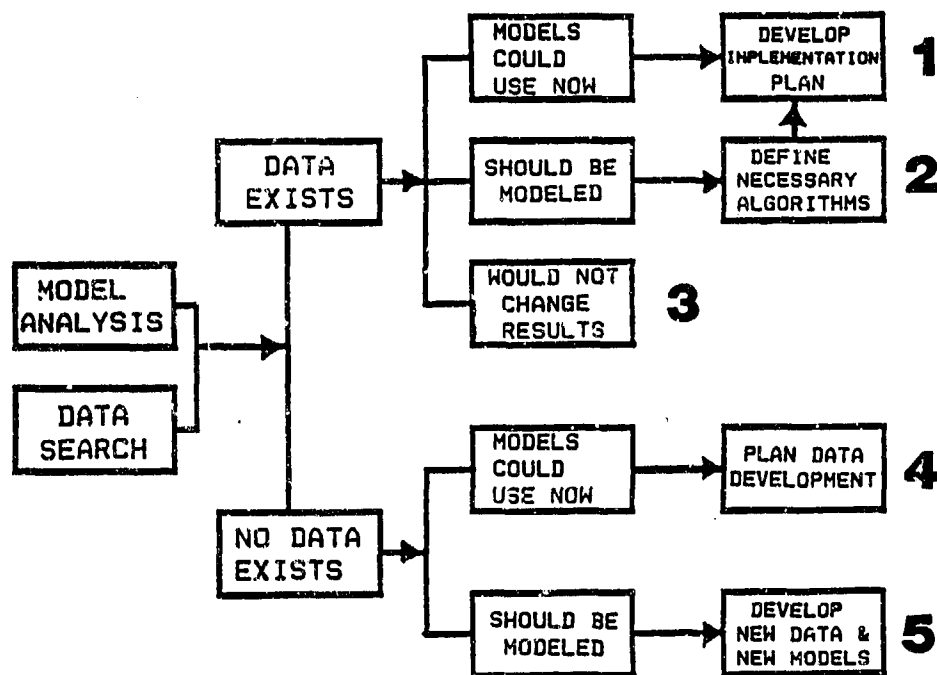
Figure 1. Study Decision Tree

7. RESULTS

a. One major finding of the data search part of the study is that there is no single source of human performance data that can be accessed directly for modeling purposes. The human performance data that is available was collected for other purposes, e.g., for operational testing or for training evaluation, and must be obtained from multiple sources. A complete set of all data that might be useful for modeling purposes cannot be generated from extant data. Another finding is that the physical and psychological limits of human capabilities suggest that the results of combat are as likely to be determined by human performance as by differences in equipment capabilities.

b. The major model analysis was of the Force Evaluation Model (FORCEM). FORCEM is a two-sided deterministic representation of land and air combat with support operations for an extended theater campaign. Other than availability of personnel for manning the equipment, human performance is not considered in the battle portion of FORCEM. A limited amount of testing of the battle module showed that relatively simple modifications could be made to better represent a human factor such as combat fatigue. The result of some of the testing is shown in Figure 2. This example shows the differences that might be expected in number of hits during one cycle of the battle module. The base line condition is with no personnel degradations and is the 100 percent level. The first condition is for all mental category IIIA (base line was all mental category II). The next is after 24 hours of sustained operations. The third is after 7 hours of combat in high heat, and the fourth combines all three of the conditions. Humans are better represented in combat service support than they are in the battle module, but variables which might change personnel performance during the period of time simulated, such as fatigue, are not considered. If fatigue from stress or continuous operations were included in FORCEM, an input assumption concerning number of hours sleep would be needed and it should be included in the personnel availability computation.
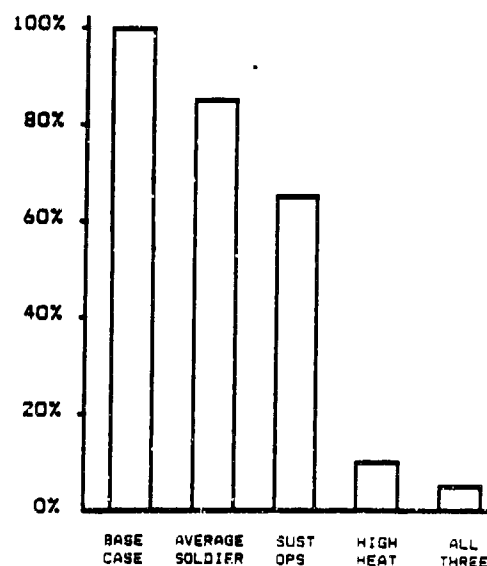
Figure 2. Average Soldiers After 24 Hours of Sustained Operations with 7 Hours of Excessive Heat

c. The Vector-In-Commander (VIC) Model was designed to use many input parameters that should be set based on human performance measures rather than on only equipment performance measures. VIC has not yet been studied in sufficient detail to determine whether additional personnel performance algorithms (pergorithms) are needed to adequately represent human factors.

8. RECOMMENDATIONS. These recommendations are for CAA management and are based on the results of both the data search and the model analysis.

a. Modifications should not be made to divisional level models (VIC) or theater level models (FORCEM) to represent human factors that do not change during combat, e.g., educational level. Either of these models could be used for that purpose by changing input data such as the probability of hit via the preprocessing programs, rather than by making changes to the models. The factors can then be tested in a sensitivity test mode.

b. Personnel performance algorithms (pergorithms) should be phased into FORCEM. They should be designed so that the user may run FORCEM with or without pergorithms. The pergorithm that should be developed first is one for which reasonable data are available and which is likely to make differences in combat results. Another criterion is that it will be difficult to represent in FORCEM by introducing it to a lower level model and allowing the results to "sift up" to FORCEM. Combat fatigue fits the criteria. An associated parameter is the assumption for number of hours sleep that will be allowed once the unit is committed to combat. This assumption affects personnel availability.

c. If VIC results are to be meaningful, the baseline data base for human-sensitive parameters should be developed prior to the first use of VIC in a study. Otherwise, it will be necessary for individual analysts to choose input values based on a limited knowledge of appropriate ranges.

d. Some of the issues shown in Table 1 are important to combat results, e.g., suppression. Techniques for modeling them should be developed in time to use data as they become available. The other issues are already included in many combat models and better data is urgently required, e.g., breakpoints. Therefore, it is important that work be initiated which will quantify them for combat model use.

Table 1. Issues for Future Consideration

Important to combat results	Important to results of models of combat
Winter/summer	Combat worth
New guy factor	Breakpoints
National characteristics	Movement rates
Suppression (from fire and virtual)	
Surprise	
Unit behaviors	
$C^3 I$	

4

9. SUMMARY. This project found that human data can make large differences in combat results. Factors that make large differences in combat results should also make large differences in the results of models of combat. There are not yet data bases on human performance and behavior which are sufficiently complete for use in all levels of analytic combat models. Sufficient human performance data does exist to develop a data base that includes both equipment and human data for parameters such as probability of detection and probability of hit. This report demonstrated that FORCEM could be modified to reflect the detrimental effects of environment and stress on human performance. This project also showed that preprocessing and sensitivity testing could be used to evaluate the effects of soldier characteristics such as mental category that do not change appreciably during the combat period. The results of this project include a list of human data that should be included in combat models, an implementation plan for that data, and a list of important variables that may need more study before they can be incorporated. One additional benefit from this study is the development of a common vocabulary for use of human data in combat models. This vocabulary will be used for communication between the modeling community and the behavioral and human factor research community.

MODEL EFFECTIVENESS AS A FUNCTION OF PERSONNEL (ME = f(PER))

CHAPTER 1

BACKGROUND AND METHODOLOGY

1-1. INTRODUCTION. This chapter describes the background, objectives and methodology for the ME = f(PER) Study.

1-2. PROBLEM. Although human participation and influence are pervasive in actual combat, the effects of human factors or human performance are frequently considered only implicitly, if at all, in combat models. The need for better representation of the human element in combat models has frequently been identified during the past 30 years. Representative statements are shown in Figure 1-1.

1954   "AS PART OF A CONSIDERATION OF INFANTRY COMBAT

EFFECTIVENESS, IT IS IMPORTANT TO BE ABLE TO

DETERMINE THE EXTENT TO WHICH COMBAT AFFECTS

THE INFANTRYMAN'S PERFORMANCE"

(STRESS IN INFANTRY COMBAT, OPERATIONS RESEARCH OFFICE)

1971   "THE HUMAN PSYCHOLOGICAL PROCESS IS AT THE

HEART OF THE PROBLEM"

(REVIEW OF SELECTED ARMY MODELS, DEPARTMENT OF ARMY)

1986   "EACH GROUP IDENTIFIED THE LACK OF DATA AND

MODELING ATTENTION ON HUMAN FACTORS AS ONE OF

THE MOST SERIOUS PROBLEMS IN MODELING TODAY"

(CLAYTON THOMAS, MORE OPERATIONAL REALISM IN MODELING
OF COMBAT WORKSHOP REPORT, PHALANX, BULLETIN OF
MILITARY OPERATIONS RESEARCH, VOL 19, NUMBER 2,
JUNE, 1986)

Figure 1-1.   Selected Quotes

1-3. BACKGROUND

a. Models created for evaluating and comparing individual weapon systems are usually considered the origins of combat models. When the equipments are similar and it can be assumed that the same crews would operate each of the systems being compared, then the differences in human performances may produce negligible differences in model outcomes. Differences in tactics, doctrine, and national characteristics can make very large differences in soldier performance. Therefore, when the modeler compares a weapon system for the Blue side against a weapon system for the Red side, the assumption that crews make no differences is much less valid. The importance of the soldier and crew to combat outcomes has long been recognized by military leaders, yet many of our present combat models assume that all human tasks are performed perfectly. The research on human reliability suggests that 50 percent or more of system failures may be traceable to human error (Ref 1).* Models of processes in which humans are important to the real-world outcomes (such as combat) may contain gross errors when they contain data on equipment performance and ignore human performance.

b. Human performance data are not as available as equipment performance data. Equipment data are heavily scrutinized by all echelons of the Department of Defense (DOD) and the US Congress. Thus, reams of equipment data on every system are readily accessible because they are collected as part of the research, development, and acquisition (RD&A) process. The Army is beginning to place more emphasis on the human aspects of weapon systems during the acquisition process as evidenced by the recent emphasis on Manpower and Personnel Integration (MANPRINT). The MANPRINT program requires that human capabilities be included in the earliest phases of RD&A and that human data will be collected, analyzed, and scrutinized with the equipment data. A recent article provides one view of the reason for lack of human data in these equipment tests and, since the article is written by a scientist in the RD&A community, provides hope that more attention will be paid to the need for human data in the future:

> "For most tests, the human is part of the total
> system. Yet, all too often this critical part of
> the total system gets last priority. Since
> testing is a scientific endeavor, it is usually
> performed by technically trained people. These
> technicians like to deal with equipment problems
> more than with people problems . . . the tester
> who ignores the human element has only tested a
> part of his system and may be ignoring the most
> critical part." (Ref 2)

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*Reference numbers refer to the references listed in Appendix C.

Combat models that include many of every available type of weapon system that must be detected and fired upon can no longer assume that all crews are equivalent and that the only data relevant to the results are the equipment differences. As the rest of the Army becomes more sensitive to the need for including the human component in any analysis, the modeling community must also become aware of this need and begin to prepare for answering the questions that will be inevitable.

1-4. PURPOSE AND OBJECTIVES. The purpose of this project is to identify those areas in which the modeling of battlefield processes in the US Army Concepts Analysis Agency (CAA) could and should be modified to include the effects of human factors and human performance. The specific objectives are:

    a. Identify the combat processes which are potentially most sensitive to the effects of human factors or human performance.

    b. Determine existing data base elements and process algorithms which will permit appropriate modifications of the models of the combat processes by simple changes to the data base.

    c. Define and verify new algorithms and data that are necessary to generate the additional human factor functions that should be included in the combat model processes.

1-5. SCOPE

    a. The first focus of this research is human factor information that would be suitable for inclusion in the CAA combat models.

    b. The other focus is on the combat models to determine which is most suitable for inclusion of human data. It is probable that some human data will be appropriate for each.

1-6. LIMITATIONS. With the limited resources of a fellowship project, combat model changes cannot be made, nor can a human data base be developed. However, one of the products of this research is an implementation plan for making recommended enhancements to the combat models.

1-7. KEY ASSUMPTIONS

    a. Enough verifiable data exist which can be used as a basis for testing the concept of modeling human performance in combat.

    b. Algorithms can be developed to model human factors.

    c. These algorithms can be adapted to the CAA combat models.

1-8. METHODOLOGY. Two concurrent approaches are used in this research. The first is the data search, the second is the model analysis. The data search is not constrained by requirements of current combat models, and the model analysis is not constrained by the availability of data. Near the end of the project, the results of the two efforts are compared to determine areas of overlap.

a. Data Search

(1) **Purpose.** One purpose of the data search is to discover the human variables that are thought relevant to the results of actual combat. Whether or not present combat models can be modified to use human data, it is important to identify human variables which may determine combat results. Unless the variables which may differentiate combat results are known, it will never be possible to design combat models which include the critical variables. The other purpose of the data search is to determine whether sufficient data on the critical variables are available for use in the combat models. Where sufficient data are available, an attempt should be made to modify the presently used combat models. Critical variables for which sufficient data do not exist define a priority need for human research.

(2) **Method.** The major source for the literature survey is the Defense Technical Information Center (DTIC). The purpose of the literature survey is to collect a representative sample of the literature, and not to collect every relevant document. As documents are received, their bibliographies are examined to obtain additional references. Possible data availabilities are discussed with personal contacts from US Army Research Institute for the Behavioral and Social Sciences (ARI),* Army Materiel Systems Analysis Agency (AMSAA), Operational Test and Evaluation Agency (OTEA), US Army Research Institute for Environmental Medicine (USARIEM), and Walter Reed Army Institute of Research (WRAIR). The types of information looked for include a delineation of the human variables that can determine the results of actual combat, and, for these variables, the numbers or curves that should be used to represent them.

b. Model Analysis

(1) **Purpose.** In a top-down analysis, the model analysis technique most frequently cited as correct is one which would start with the question to be answered, followed by functions which should be modeled, desired aggregation level, etc. **(Ref 3).** However, new model design is a major effort and is not needed or desired for this project. It will probably be several years before there is any drive to replace the models now in use at CAA. In the interim, potential improvements for them are continually identified and made. This project shows that one of the potential improvements is the use of additional human factors.

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*Dr. Irving Alderman, ARI, provided continuing technical support during the time of this fellowship.

(2) **Method.** The main focus of the model analysis is the Force Evaluation Model (FORCEM)--the major theater-level analytic model used by CAA. FORCEM is a two-sided, deterministic representation of land and air combat and support operations for an extended theater campaign. It was developed recently by CAA, and it is the highest level of the hierarchy of Army analytic models. In the sense that all other actions in FORCEM are based on the results of the battle module (e.g., combat support, the posture, the movement rates, whether other units are moved forward for the next time cycle, etc., are all based on the consumption and attrition of battle), the battle module of FORCEM is the main driver of the entire model. Therefore, the battle module is studied in detail to determine which human factors are already represented and which are not represented but should be. The criterion for inclusion is that they have a significant influence on the outcome of actual combat. The Vector-In-Commander (VIC) Model will be used to generate division-level results for use in FORCEM. It seems reasonable to analyze VIC to determine whether human data should be added to it, either irstead of or in addition to FORCEM. VIC is also a two-sided, deterministic representation of land and air combat, but it uses weapon system level information to produce division-level outcomes. The capabilities of the weapon systems are the major elements considered in the FORCEM battle module and in VIC. Therefore, for this project, the representation of the weapon system is important. When weapon system capabilities are represented, they should represent the combined capability of the weapon and the operator or crew. Figure 1-2 shows the relationship of the weapon system representation to the higher order, top-down analysis questions that are skipped for this project.
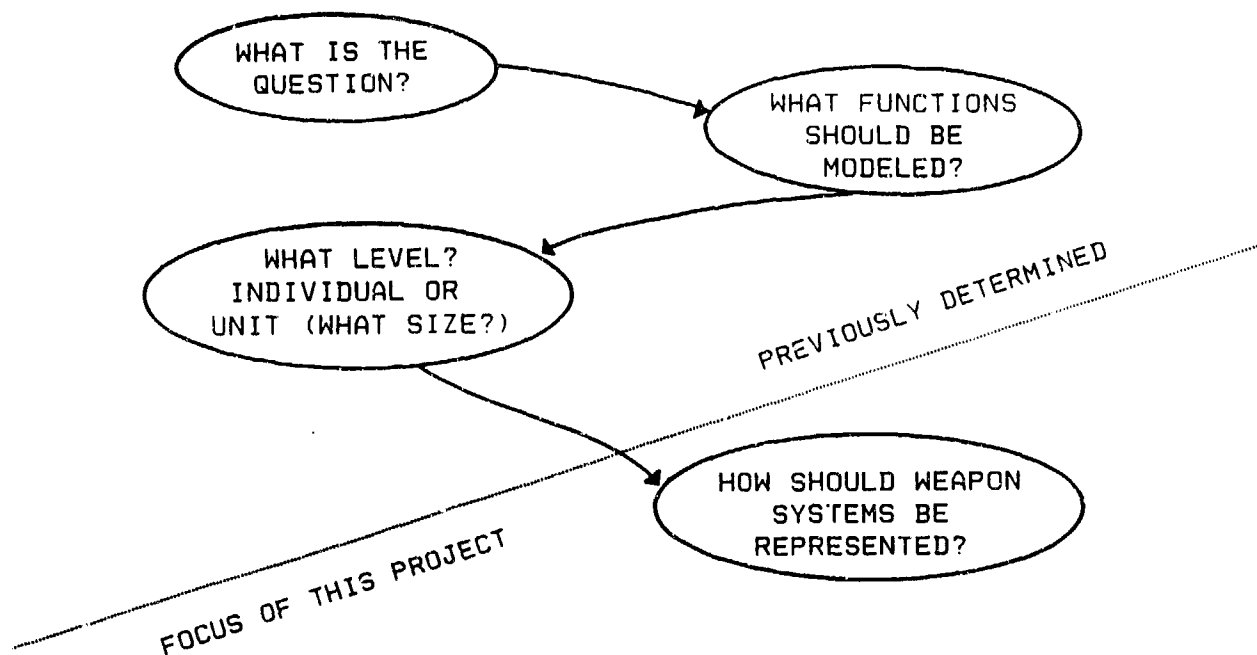
Figure 1-2. The Systems Approach

c. Combining Results

(1) **Purpose.** Future directions depend upon which variables are identified in both prongs of this research and which are identified in only one. This is represented pictorially in Figure 1-3. Where values for critical variables can be found in the literature, future modeling work will be concentrated in branches 1 and 2 of the study decision tree, depending upon whether the personnel performance algorithms (pergorithms) are already coded in the model or whether the pergorithms are not yet developed. If values are found for variables that do not influence the outcome of actual combat, they should be relegated to branch 3--no further work is necessary for those variables. Branch 4 is taken when the model analysis reveals that the models are expecting inputs for which no adequate data source can be identified; this represents the identification of a critical need for human performance research. Branch 5 represents a finding that there are combat critical variables for which neither data nor a modeling technique have been created. In this latter case, both the modeling community and the human research community need to be involved so that future combat models will adequately represent combat.
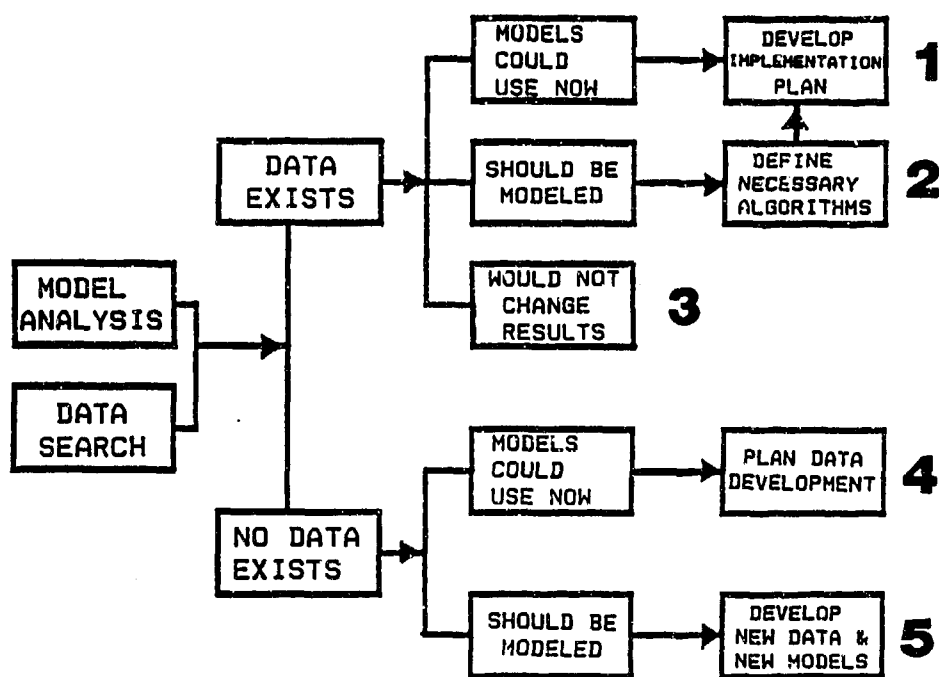
Figure 1-3. Study Decision Tree

(2) **Method.** When the two separate parts of this research are completed, a simple comparison of variables identified by each will be made. This comparison provides the information needed to place the variables on one of the five branches of the study decison tree.

1-9. SUMMARY. This chapter described the purpose and methodology of the ME = f(PER) Study. The purpose of this study is to identify areas in which the CAA combat models should be modified to better represent soldier performance. The first thrust is the data search which identifies human factors that are thought to sway the results of actual combat and should be considered for inclusion in combat models. The data search is not limited by current combat model requirements. The second thrust is the model analysis. It identifies the variables that are now in combat models which either provide for inclusion of human data or which could be modified to do so. The model analysis is not constrained by data availability. Finally, the results of the two major thrusts are compared to identify those areas in which additional work is required by the modeling community, by the human research community, or by both.

CHAPTER 2

DATA SEARCH RESULTS

2-1. INTRODUCTION. This chapter describes the results of the data search portion of the study. The first portion of this chapter answers some of the questions which operations research analysts frequently ask about human data:

● How can anyone know what humans will do in combat?

● Why does anyone think humans really make any difference (all the really big differences are made by the equipment, aren't they)?

● How would we decide which variables to use?

● Since both Red and Blue are human, don't human factors effectively balance out when they are applied to both sides?

The next sections discuss variables which affect (moderate) system performance. Although they may not affect the equipment performance when the equipment is considered without the soldiers, a consideration of the total system must include these environmental and stressor variables. Next, performance measures which can be used to replace or supplement present equipment measures are discussed. Finally, some topics that seem to have great relevance to combat outcomes and are related to human (or system) performance, but for which we may have difficulty obtaining enough data, are introduced. Throughout the portions which discuss human variables or variables which may moderate system performance, the availability of data is discussed. Rather than duplicate the many literature reviews on specific topics such as stress, this chapter is a synopsis of the author's synthesis of the Army application of the relevant data found in the literature. The complete set of references is listed by topic in Appendix D. Since many readers have never experienced combat conditions, some excerpts from anecdotal histories are included in this chapter. These passages are written by soldiers, using descriptions of actions from soldiers who have been in combat. Usually the descriptions were collected immediately after combat. They are included because they frequently portray the magnitude of the impact of human variables on the results of combat more vividly than could a mere reporting of research results.

2-2. BACKGROUND. At the beginning of this project, the consensus was that there were no data directly applicable in CAA combat models, and that there had been very little relevant research. Most operations research analysts and psychologists were sure that there is little useful information in the literature. A short review of the literature looked at the research on human performance and its applicability to the Army situation. It is true that there has not been very much research on Army combat performance. Much of the research on human performance has been performed in a

university setting, using college students as subjects. The tasks that are used to measure performance frequently seem to have little relevance to Army combat. However, when there are performance degradations found for several different variables, the research is in a highly controlled setting, and only one variable at a time is changed, then it is probable that performance will be degraded when all variables are changed at the same time in the directions that cause degradation. As can be garnered from anecdotal histories, variables that affect human performance will frequently change in the degradation direction during combat. During the past 20 years, there have been numerous literature reviews and attempts to relate research results to combat performance. This chapter is meant to impart a flavor of the information that is available without replicating the complete reviews that are referenced. The summaries are the author's interpretations of the research found.

2-3. WHY SHOULD WE BE INTERESTED IN REPRESENTING HUMANS IN COMBAT MODELS?

"Though the rise of industry had enormously enhanced the power which states can deploy against each other in war, and the improvement in weapons has almost infinitely extended the range of a general's reach, the predicament of the individual on the battlefield has, at whatever moment we choose to examine, still to be measured on one quite short scale: that of the physical and mental endurance of himself and his group. Men can stand only so much of anything (and dead men are dead whether killed by arrow or high-explosive), so that what needs to be established for our purposes is not the factor by which the mechanization of battle has multiplied the cost of waging war to the states involved but the degree to which it has increased the strain thrown on the human participants." **(Ref 4)***

a. **Amount of Fire.** A draft report on results of an analysis of data from the National Training Center (NTC) compares the rate of fire, hits, and other variables with the values that would have been expected by doctrine **(Ref 5)**. According to this data, the intensity (casualty percentage) and pace (casualty rate in terms of time) of battle would be significantly less than that predicted by our models. If we are interested in the logistic support, then we should be interested in the casualties, both total numbers and the rate. It is interesting to note that of the high ranking officers who write about war, a very large percentage write about people and how people made the difference in the combat outcomes. Sometimes they first praise their equipment, then tell us that even so, it was the courage, morale, spirit, cohesion, et cetera, of the soldiers that really won the battle. Even S.L.A. Marshall praises the troops while he tells us how few

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*Reference numbers refer to the references listed in Appendix C.

actually fire. According to Marshall, only 15 to 20 percent of the men ever fired in any one European battle during World War II (Ref 6); somewhat more than that, perhaps double the percentage fired during Korean battles (Ref 7); and a higher percentage of crews fire than of individual soldiers (Refs 6 and 7). The difference may be improved training. The Army would like to believe that training has been improved enough that nearly 100 percent would fire. It may have been due to another reason. During World War II it was reported that a much higher percentage of soldiers in the Pacific said they were willing to kill a Japanese soldier than the percentage in Europe who said they were willing to kill a German soldier (Ref 8). Some writers propose that it may be because the enemy in Europe looked too much like our own soldiers; it was too similar to firing at one's own buddies. In the Pacific, however, the other side looked very different. In Korea, also, the other side was of a different race than the vast majority of our troops.

b. Crew Weapons. Crew weapons are usually firing at other weapon systems where the crew cannot be seen directly, or they are firing at a location rather than at a specific target. There may be no difference that is attributable to training; it may all be attributable to being easier to fire at an impersonal target. Or, it may be attributable to entirely different factors such as differences in tactics, target types, or working as part of a team. Note that, according to Marshall, crews still only fire "more;" 100 percent did not fire. Artillery crews are, in general, much safer prior to beginning their fire than are the infantry soldiers or the tank crews; they may have felt less inhibited about firing because they felt the enemy could not see them. Apparently the tank crews also fire more than infantry soldiers. They may have fired more because they felt slightly protected by the tank armor and so, spent more time looking for a target than for cover, or the targets they look for are easier to see, or some other reason such as peer pressure.

c. Probability of Firing. Our models have very precise decision rules built in that are normally something like this: "from all targets that are within line of sight or within range for sensors, choose the most valuable target and fire enough to kill it, choose the next most valuable target and fire enough to kill it, choose the next . . ." The probability that soldiers or crews will find all targets within range or line of sight is not 100 percent. The probability that they will choose the most valuable target rather than the first they see is probably very low. The probability that they will see it in time to fire is lower yet. A recent report (Ref 9) evaluated an infantry platoon's performance during simulated engagements using the Multiple Integrated Laser Engagement System (MILES) to measure the number of weapon fires and the number of hits. Although more than 20 percent fired their weapons in all of the engagements, if each exercise had been an actual battle, no more than 20 percent of the platoon would have both fired their rifle and been alive at the end of any engagement to tell about it. In this case, the reason for the smaller percentage was neither fear for their own life nor squeamishness about firing at a person similar to themselves. It was simply that they did not find any targets or did not find them in time to fire. An interesting statistic to contemplate is that

only 44 percent of Army officers and enlisted men in Europe reported that they had "been in actual combat in this war" (Ref 8). In the Pacific the percentages were only 40 percent of the Army officers and 33 percent of the Army enlisted men.

2-4. WHAT DATA ARE NEEDED? If additional factors are to be built into combat models, there are several criteria that must be met. The first three may seem obvious, but they are extremely important: the value of the factor should change during the time simulated; the factor must have the potential for determining the results of actual combat; and either the values for the factor should be different for each side, or differences in doctrine or tactics should cause the effects of the factor to be different for each side. If any of these criteria are not met, adding model code and more input requirements is adding needless complexity. Other criteria must be met in order to effectively model the factor. These include knowing the variance, the shape of the distribution, the other controlling parameters, and which performances are affected. For example, if one were to model the effects of summer temperatures on tank crews, it would be necessary to know more than the upper limit of number of hours of work at various temperatures. Depending on the aggregation level of the model and assumptions played, necessary information might include having a rate of performance degradation for each type of performance with an associated maximum time length for each individual position in the tank crew, knowing whether personnel performances fit a normal (or some other) curve, what the variances for each performance are, and whether or not humidity must be known and included in the computations. For another, more aggregated model, the only usable information might be the average length of time the crew could operate at 100 percent efficiency for various temperature ranges, the average maximum time before complete incapacitation, and the rate at which some factor such as kill rate will degrade. For most models, information about recovery from performance degradation, at an aggregation level equivalent to the degradation data, will also be needed. Finally, information on how to combine multiple factors is required.

2-5. IT TAKES TWO TO TANGO. One of the arguments against including human data is that any factor that is added will apply to each side equally so that there has not really been any change. That argument is false for several reasons. First, depending upon the nations involved, there are frequently enough differences in factors such as general abilities, resistance to diseases, willingness to fight, training levels, and leadership to make a real difference in the combat results. If these could be quantified, they could also be included in combat models. The second reason is that the doctrine of the two sides is usually enough different that the same factor does not actually get applied to each side equally. For instance, if one side planned to allow each soldier 5 uninterrupted hours of sleep per night, each soldier would still be more than 90 percent effective the following day. If, however, the other side allowed the soldiers no sleep, by the end of the second day, the soldiers on that side would be only 50 percent effective, while the soldiers on the first side would still be 86 percent effective. Finally, there is the question of whether there is actually any interest in the support (the tail) required. We often hear

that in today's Army, the tail is wagging the dog. It may be partially the fault of our combat models which show the war lasting a very short time, meaning that all support must happen immediately. It takes a large infra- structure for the support to be there in the quantities specified as quickly as specified. Slowing the war may show less need for the large tail. When human factors are applied to each side to represent actual differences in the soldiers, the answers may be very different than would be produced by our present models.

2-6. REAL SOLDIERS

a. **Data in the Literature.** To change a model from one which represents equipment characteristics to one which represents system characteristics, it is necessary to determine factors that may cause the system characteris- tics to change during the combat time simulated. These factors, known as system moderators, are represented as horizontal layers in Figure 2-1. The first layer represents the factors that will allow the model to represent soldiers using the equipment rather than representing the engineering speci- fications for the equipment. For the combat part of a model, these factors include such elements as probability the soldier will detect a target, range at which the soldier will identify the target, probability the soldier will fire, and rate at which the soldier will fire. Since the values for these factors may depend upon other factors such as amount of enemy fire, they may be very different from values for similar factors that now represent only the equipment capability. In general, they may be directly substituted for the equipment values.
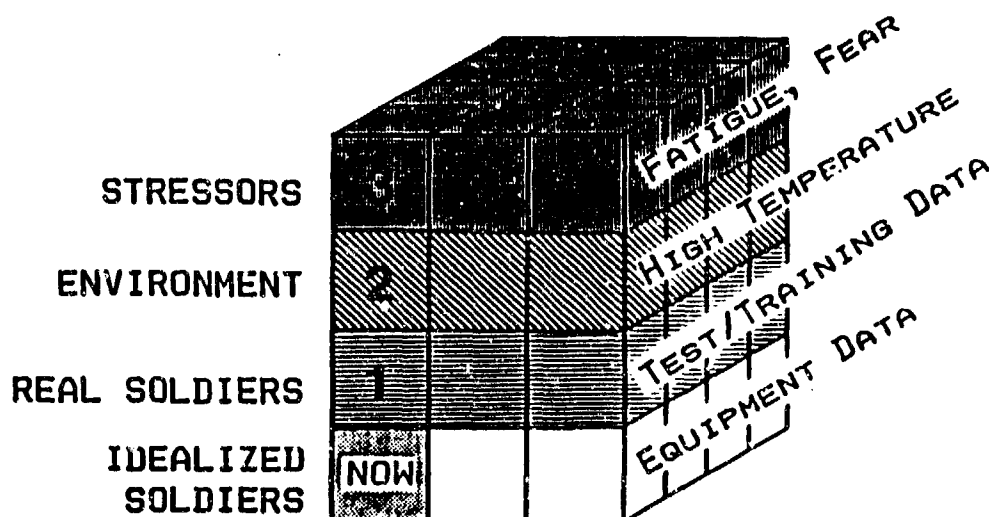

Figure 2-1. The System Moderators

b. Data Availability. There is probably more data on capabilities of soldiers to perform their combat tasks than any other topic discussed in this chapter. However, the data are collected in environments which may not be representative of combat. Some of these data are collected for the purpose of evaluating equipment performances during operational testing. Other data are collected by the individual Army schools for evaluating training. None of the data are collected specifically for a data base of the type needed by combat models. Most of the data are for individual soldiers or for individual crews; very little data are in terms of total unit performance. The NTC is beginning to collect task force data. Although there are problems with the instrumentation so that data on individual weapon systems may be suspect, it is thought that the summary unit data are accurate. More detailed examples of data availability will be given during the discussions of the columns of the cube (paragraph 2-10).

2-7. ENVIRONMENTAL AND STRESSOR MODERATORS. In this project, environment and stressor moderators are differentiated. They are shown in Figure 2-1 as layers 2 and 3 of the system moderators. The environment is considered a more easily quantified topic. It is possible to measure temperature, humidity, and altitude; observation can determine night or day, snow, rain, or fog; and there are relatively concrete descriptions for terrain representation. Stressors are more amorphous. It is difficult to tell exactly how much of a stressor is present, and what seems a very small stressor to one soldier may be a nearly insurmountable one to another. In the literature, however, the effects on the human of both environment and the parameters that are termed stressors in this report are considered stressors. In other words, the effect on the soldier of a specific amount of an environment parameter such as rain is variable--variable from one soldier to the next, and variable from one time to another on the same soldier. Both environmental and stressor variables cause similar responses in the soldier--psychological as indicated by behavior and physiological as measured in blood and urine tests. Since the environment parameters are themselves more easily measured, they are somewhat more easily studied. Since the effects to the human of environment and stressors are similar, both types are frequently discussed without differentiation in the literature. Therefore, all references in Appendix D for the environment section are combined with the references for stressors.

2-8. THE MAJOR ENVIRONMENTAL VARIABLES. Environmental variables include weather (heat, cold, rain, snow, wind, and humidity), terrain, night/day, noise, vibration, confinement, altitude, crowding, and toxic substance (requirement to wear protective clothing). The major effects of each of these variables and the results of applicable research are briefly summarized below.

a. Heat

(1) **Research.** Heat can degrade performance, particularly in physical work. Since there is clear evidence of life endangerment from physical labor in high heat, there is a relatively large amount of research by both

government and private industry. Technical Bulletin, Medical 507, Prevention, Treatment and Control of Heat Injury (TB MED 507) is used by all the military services (Ref 10). Although TB MED 507 gives the maximum safe limits for various types of work at different temperatures (See Figure 2-2), the particular item of information most needed for combat modeling purposes is the curve of performance decrement expected during the work time. It is unlikely that all performance is 100 percent effective until the time worked reaches the maximum and then drops to zero. Acclimatized soldiers can withstand the effects of heat for longer periods than nonacclimatized soldiers, but acclimatization cannot give them complete protection.

HOURS OF HEAVY WORK BEFORE
DANGER OF HEAT EXHAUSTION

RECOMMENDED MAXIMUM
FOR 2 HOURS WORK
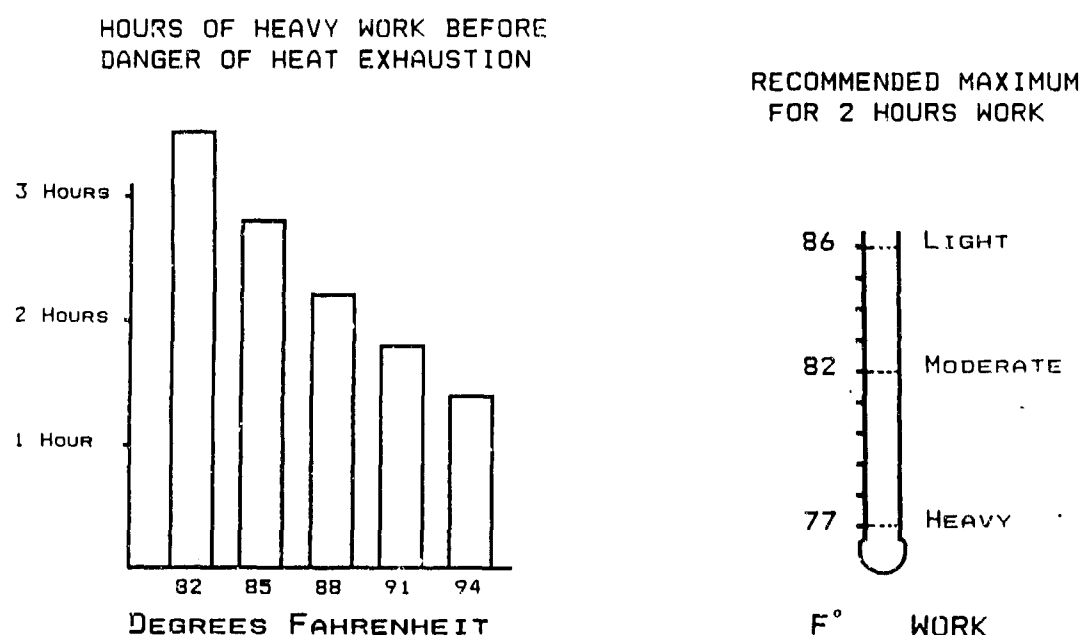
Figure 2-2. Maximum Exposures for Heat Measured with "Wet Bulb Globe Temperature"

(2) Anecdote

"All of this happened right after the noon hour. The temperature was around 104 degrees . . . as Mills and Yocum neared the end of their backbreaking labor, there were seven more men to be carried to the dustoff. That many of Mills' platoon had passed out from heat, in which condition a man is more helpless than if he is one of the walking wounded." (Ref 11)

b. Cold

(1) **Research.** Probably because it is usually thought that clothing and shelter can protect humans from cold, there is less published literature in DTIC on the effects of cold than on the effects of heat. However, since both cold and protective clothing or the requirement for shelter may cause performance decrement, cold is mentioned in a few literature surveys. One literature review **(Ref 12)** on the effects of cold on task performance found that tasks requiring fine manual dexterity such as manipulation of knobs, switches, push-buttons, nuts, screws, and nuts and bolts show major performance deteriorations, mainly from reduced tactile sensitivity. Studies with conditions of warm body-warm hands, warm body-cold hands, cold body-cold hands and cold body-warm hands showed that the performance decrement is due to cold hands, not to body temperature. Hand grip strength with exposure to extreme cold for long periods (3 hours to air temperatures of -23^0 to -26^0 C) showed 28 percent drop, and another showed 21 percent decrement after subjects immersed their hands in 7^0 C water for 15 minutes. Although the extremities can be protected, gloves or mittens are sufficiently bulky according to that review that, "personal protective equipment merely exchanges one source of performance decrement for another." Studies of aircraft maintenance work showed that workers frequently had to remove mittens or gloves for a task requiring manual dexterity with a substantial loss of effective working time. These authors cite the paucity of literature on task performance in cold environments, particularly mental performance. The two studies that were found by Findikyan, et. al, suggested that there may be some cold-related, mental performance decrement. However, these authors report that there is little support for common beliefs that cold can cause deterioration of morale, anxiety, increased irritability, depression, sleep loss, and personal untidiness. Acclimatization can be achieved within 1 week, but 2 or 3 weeks will allow soldiers to reach a steady state. As well as feeling more comfortable in a cold environment, acclimatization to cold can mean better performance on tasks that were learned in a cold environment, although not without performance decrement.

(2) Anecdote

"The night was bitterly cold. The thermometer read 18 that night at Suwon and it must have been 5 degrees lower on the peak. Easy Company was not insulated against it. Lacking foxholes, Glunt's men were also without overcoats, parkas, or bedrolls. Knowing that the weather would be freezing on the peak and that staying there through the night many of their members would be victims of frostbite, they still had taken this chance with eyes open, rather than further reduce their ammunition load so that they could carry bedrolls or parkas. Due penalty was exacted. They had to fight bare-handed through the night so that they could work their weapons; that necessity increased the degree of exposure. They had no time to change to dry socks and the sweat from their exertion froze inside the shoepac. On the day following, eight of their number had to be hospitalized as frostbite cases. The critique of this company was conducted 3 days after the action. At that

time there was not one member present but could exhibit a few
swollen fingers, or toes, or an ear which was a gift from the
weather on Hill 440. Glunt had three frozen fingers, Wallace
two, Abrahams two. Jones had a frostbitten ear. This was the
common lot of the company. The men were still doing duty in the
front line." **(Ref 13)**

c. Terrain

(1) **Research.** No references describing differences in individual
soldiers' combat performance based on terrain differences were found in the
literature. Unit performance measures such as movement rates probably
should be differentiated based on terrain type. Wainstein **(Ref 14)** warns
that all too often combat models use movement rates based on Parsons and
Hulse (reprinted in Ref 14) without realizing that they were at best esti-
mates, and at worst very wrong.

(2) Anecdote

"Hill 440. By any sensible standard it should be called a moun-
tain. It is almost sheer rock . . . the great hill mass was
obviously an infantry problem; armor could neither scale it nor
work in close enough along the base to put effective fire against
its crest . . .. In about one and one-half hours of straight
climbing Sibley's platoon gained the first knob and stopped for a
breather before moving on into the saddle. Part of the way it
had been hand-over-hand with the weapons and radio men particu-
larly having a hard time in negotiating the rock slabs. There
had been no brush cover but neither had there been fire; what
helped mainly was that the day was just cold enough to be bracing,
the temperature being about 25." **(Ref 13)**

d. Night Operations

(1) **Research.** Night vision devices and other types of sensing devices
to aid the soldier in night operations have been developed since the Korean
conflict. So far as one can tell from the general Army literature, the
Army leadership seems to assume that these new devices will solve the prob-
lem with combat at night. In 1974, General Research Corporation completed
a project for the Army in which "the desirability, the need, and the impli-
cation of attaining the capability for conducting operations at the same
level of efficiency throughout 24 hours for periods up to 30 days was inves-
tigated" **(Refs 15 and 16)**. As a result of their assessment of the tech-
nologies, they concluded that improvements could still be made, but that
night operations with near daylight efficiencies were not possible in the
foreseeable future. More recently, the US Army Safety Center analyzed 16
Black Hawk (UH-60A) helicopter accidents which occurred between October
1979 through October 1983 **(Ref 17)**. Although an original requirement was
that the Black Hawk should be capable of conducting "day and night missions
under visual and instrument conditions," the largest single cause of acci-
dents was crew error during night flight (6 out of 16). There are many

problems associated with night operations which cause degraded human performance. Examples include the interruption of the soldiers' normal work/rest schedules, the effects of sleep loss on performance, night vision devices are difficult to use without a feeling of serious eye strain, and the user has no peripheral vision while using them.

(2) Anecdote

"There is a special hazard to infantry in night defense, revealed in a number of the company perimeter fights, which comes of taking loose ammunition into the ground to be defended . . . these were excellent combat companies and had so proved themselves in the fight until that time. Yet such was the pressure of the dark and the enemy fire, and such the consequent nervous excitement, that the NCOs found they were unable to open the grenade boxes; after struggling vainly with them for many minutes, they at last dashed them on the rocks. Then the grenades spilled out over the hillside, and men had to crawl around, feeling for them in the dark."
(Ref 13)

e. **Toxic Substances.** Most of the research in this area is related to the soldiers' ability to perform their specialty tasks while wearing the special protective clothing that is required when either toxic substances or the threat of toxic substances is present. Findings range from no performance differences **(Ref 18)** to complete inability to perform any task correctly **(Ref 5).** Apparently the major problems are the heat buildup inside the clothing (in which case performance decrements associated with high temperatures should be expected), the inability to perform work requiring manual dexterity with the heavy gloves on, and to see well with the face mask in position. The end result of prolonged exposure to heat is extreme fatigue, and the result of fatigue is degradation of thinking and decisionmaking skills. Therefore, the tests that require soldiers to perform tasks that are so well practiced that they can do them without thinking about them will show less decrement than tasks which require the soldiers to decide what must be done next. Any task which requires vigilance will probably show large performance decrements. Since there is a team at CAA which is now working on developing FORCEM (Force Evaluation Model) modifications for toxic substance environment, no further discussion will be in this report.

f. **Other Environmental Factors.** These factors are discussed very briefly because they are frequently mentioned as either environmental problems, or as expected stressors for the soldiers. Although they are mentioned more often than research is performed on them, there seems to be no evidence that any one of them will be especially detrimental to soldier performance. It may be that the sum of a variety of these could be very stressful while the effects of each one are too small to measure.

(1) **Humidity.** Humidity seems to cause no direct performance decrement, but magnifies effects of heat. It does not seem to produce performance decrements when combined with cold in a research environment. However, humidity is expected to be a particular problem in confined spaces, for example tanks and armored personnel carriers (APC).

(2) **Noise.** Noise level inside our tanks, APCs, and on the battlefield is high enough to cause both short-term hearing loss and long-term injury. It does not cause performance decrement directly, but it makes verbal communication more difficult (either because of short-term hearing loss or from the use of ear plugs which themselves also affect ability to communicate). In this sense, noise causes performance decrements, either from missed communication or additional time required for communication.

(3) **Vibration.** Although vibration is uncomfortable, there seems to be no actual performance decrements attributable to it. One source believed that men could take vibration longer than could the equipment that is creating it **(Ref 19)**.

(4) **Confinement.** Although frequently mentioned as problems for tank crews along with noise and vibration, research by Navy and National Aeronautics and Space Agency (NASA) **(Ref 20)** using periods that are probably longer than required for tank crews (48 hours to 30 days) found physical problems with reduced circulation when confined with little opportunity to move. "Few decrements in performance were observed in psychomotor tasks, perceptual tasks, or intellectual tasks. Some decline in performance was observed in complex monitoring tasks such as radar monitoring or aerial reconnaissance. Nevertheless, it would appear that confinement alone should not affect performance greatly for periods of 48 hours or less."

(5) **Altitude.** Although altitude is of concern for the Air Force, it is less likely that the Army will fight at high enough altitudes that this is of concern. However, combat modelers should be aware that there is the possibility that a scenario could require fighting in mountainous areas that are of high enough altitude to cause performance decrements in some soldiers and that altitude could affect helicopter crew performance.

(6) **Crowding and Isolation.** These are frequently mentioned as problems by authors writing about future wars. However, the little research that was found showed no performance decrements in college students or in submariners.

g. **Data Availability.** The environmental data most needed are those that most affect combat results. Presence of toxic substances would most affect human performance in combat **(Refs 21 and 22)**. Definitive data on the effects are needed for model modifications that are already in development. The factors next most likely to affect combat are the effects of weather and of night operations **(Refs 23 through 28)**. The general category of visibility can subsume day, night, fog, and the visibility aspects of other weather such as rain and snow. Since the temperatures of equatorial and arctic zones, and both summer and winter in the temperate zones, can cause performance decrements, data are needed for them. Further, if

research on terrain effects is conducted, it might be worthwhile to deter-
mine whether the impediments due to mud and snow are significant. At least
some training evaluation data (e.g., tank gunnery qualification tests) are
collected for both night and day conditions. Since the date of the test
should be available, it may be possible to determine a temperature range.
Research on work performance in heat and cold has been conducted at the US
Army Human Engineering Laboratory (HEL), and further research is now being
performed at the US Army Research Institute for Environmental Medicine
(USARIEM). These are possible sources of data for modeling purposes.
Effects of other parameters such as mud, snow, and partial visibility
(e.g., fog) are probably not available. Although it seems probable that
data similar to the tank gunnery data are collected for other types of
weapon systems, existence of such data has not been verified. If data are
needed on altitude, Air Force research is the appropriate source.

2-9. STRESS VARIABLES

a. **Stress Research and Literature Reviews.** A 1966 report by Richard P.
Kern, one of the FIGHTER project reports, describes a conceptual model of
stress **(Ref 29)**. It provides a context which helps to understand the rela-
tionship between the results of research on stress and the combat behaviors
that are reported by authors such as S. L. A. Marshall **(Refs 6, 7, 11,
and 13)** and Dandridge Malone **(Ref 30)**. The most useful literature reviews
on stress are two recent reviews from ARI field units (one was by contract)
(Refs 20 and 31) and one from WRAIR **(Ref 32)**. The review by the Fort
Leavenworth Field Unit was written for use with the Army Model Improvement
Program **(Ref 31)**. The report by the Operations Research Office (ORO)
(Ref 33) on physiological measurements of soldiers in Korea who were actu-
ally in combat, one group in intensive combat for 5 days, another group who
were in a defensive, less intense situation for 13 days, should not be
ignored because it is old. It is the first, and seems to be the last,
actual quantification of physical differences (from blood and urine tests)
between a control group and soldiers in real combat. Other Army stress
researchers could validate the physical level of their subjects' stress by
comparison with these data. The rest of the reports listed for this sec-
tion in Appendix E are oriented to Navy or Air Force concerns. The human
behavior and performance reported on would be applicable to Army soldiers,
but it is not likely that Army tank crews will be confined to their tanks
nearly so long as Navy men are to their submarines, nor does the Army have
so much concern with flight times which require continual alertness for 12
hours as does the Air Force. Nonetheless, some of the data is reported
only in these reports, the information on relative lengths of recovery time
versus the length of the stress is applicable to Army, and they are useful
as an overview to the whole spectrum of human performance research. The
major combat stresses are thought to be sleep deprivation and fear. Sleep
deprivation is frequently subsumed in a larger category called fatigue or
combat fatigue. Combat fatigue may include fear and other deprivations
such as food and water and effects of environmental variables such as
weather and terrain.

b. **Fatigue Research.** Most university research on fatigue has been focused on loss of sleep and the length of optimum work/rest cycles. In general, performance decrements should be expected after 18 hours of continuous work after the last rest cycle in which rest was long enough for complete recovery (12 to 15 hours of continuous sleep to recover from sleep loss, several days of rest to recover from combat fatigue). In combat, soldiers will be subject to additional stress-induced fatigue from simultaneous psychological factors such as fear and feelings of inadequacy, confinement, or isolation (in tanks or bunkers); and physiological factors such as inadequate rest facilities, irregular and perhaps inadequate rations and water supply, and continuous performance of physically difficult tasks. A dramatic example of the results of fatigue was provided in a recent newspaper article: "Fatigue among overworked launch-control workers at Kennedy Space Center brought the shuttle Columbia within 31 seconds of launching without enough fuel to reach proper orbit last January 6, just 22 days before the shuttle Challenger blew apart, according to newly released information from the Rogers Commission" (**Ref 34**).

c. **Continuous Work Research.** There are many references to university research studying ability to perform tasks continuously. These are not really representative of combat operations which require many different tasks, with varying repetitions and at random times. Attempts to replicate university findings with field tests tend to find much less performance decrement (**Ref 35**). Apparently, the field tests allowed time for people to take unofficial rests (while riding in the back of a truck, for example), which is not the same as performing the same task continuously. More recent work, particularly aimed at finding the source of the discrepancy has found that with sleep loss, people tend to rest even on their feet or while attempting to perform a task. If, for research purposes, the task performance is required intermittently over a long period of time, people can teach themselves to perform the task while the researcher is measuring the performance, then catnap during the lull in order to perform the task again for the researcher. It is not that they perform a task incorrectly when they are performing it nearly so much as that they are likely to not perform it at all unless someone wakes them. Translated to soldier terms, it might mean that rather than not being able to hit targets they find, they would tend to not look for a target, hence not find one.

d. **Fear.** Although the Army attempts to provide realistic training to its soldiers, the one factor that will always be missing is fear. Yet fear is a topic that is pervasive in combat anecdotes. The symptoms of fear reported by 45 percent or more of the troops in combat divisions during World War II (**Ref 8**) include violent pounding of the heart, shaking or trembling all over, feeling sick at the stomach, cold sweat, feeling of weakness or feeling faint, and feeling of stiffness. Although fear may sometimes help a soldier fight better for at least a short time, the effects of fear seem to magnify the effects of combat fatigue. In fact, many of the reported symptoms seem similar to the effects of fatigue. An important quantification would seem to be whether combat fatigue is magnified by fear and the amount of the magnification. Kern (**Ref 29**) and Stouffer, et al. (**Ref 8**), suggest that self-confidence is necessary to overcome fear in combat, and that attempts to replicate fear during

training may, because the men may perform less well during training, have negative effects when fear in combat is actually faced.

e. Anecdote

"By that time there was hardly any activity. I was still staring at the woodline, and the guys saw how it was. 'Goff, are you all right?' Emory said, 'Are you all right, man?' 'Yeah, I'm fine, man.' Just exhausted as ****, I could hardly talk, my whole mouth was so dry. I was slumped on my knees at the second dike, just staring . . . Then we started moving toward another dike about two or three feet high. As I went, I sort of lost my head; I mean I wasn't thinking too clearly. My helmet had fallen off and I knew it was off, but I didn't try to stop and get it even though rounds were still coming in . . . I was groggy, but we had to move out; so what if I was groggy! I could hardly get up on top of the ***** tank, I was so weak . . . we turned around and came back to the plantation house on the outskirts of the original rice paddy. We dismounted and I walked about 10 or 15 feet up to the porch and collapsed. 'I can't move.' It was no laughing matter then. I was conked out on the ground. And I stayed there. My sense at that time was that I had just been in a **** battle, and that I had done nothing more than anybody else did; that I had done nothing outstanding, but that I was alive; I had survived. I hadn't even gotten hit. And at the same time, I was wondering how many people were hit, how many men had we lost? I was laying down there on this ground, and I was looking up at the sky. Finally I just closed my eyes and thought, man, if somebody came along right now and shot the **** out of me, he'd just have to do it, cause aside from the fact I was breathing, I was dead anyway. I just had to lay there, just try to get myself rejuvenated. I was completely wasted. I was shaking, just out of it." **(Ref 30)**

f. **Data Availability.** For this discussion, combat fatigue is defined as the cumulative effects of sleep loss and other stressors of combat, both psychological and physiological, which affect soldiers who are engaged in combat. However, except during an actual conflict, it is impossible to accurately measure these cumulative effects, and during the conflict, it is impossible to measure the effects of any one stressor or environmental condition. With these qualifications, however, there have been several projects which have created quantitative data which could be used in combat models to represent combat fatigue. Continuous operations on the battle-field create combat fatigue in the soldiers, so studies on continuous operations are applicable. The major ones are briefly summarized below. A more detailed discussion may be found in Appendix F. As previously mentioned, Army research on effects of stress should compare physical measures with those collected by ORO in Korea.

(1) Field Manual (FM) 22-9, Soldier Performance in Continuous Operations (Ref 36), contains vivid, verbal descriptions of the expected effects on soldier performance of continuous operations. For selected combat duty positions, charts are provided which show the expected effects over time for 5 days. The FM states that the charts were derived using "mathematical formulations." The data were actually created using the Performance Effectiveness of Combat Troops (PERFECT) computer model which is described in the next paragraph.

(2) The PERFECT Model was developed for ARI by Applied Psychological Services (Refs 37, 38, 39, and 40). The PERFECT Model computes performance over time for each soldier in a small unit. PERFECT combines task analyses of Army jobs with results from laboratory research on topics such as sleep loss, noise, visual acuity, and reasoning abilities.

(3) The Historical Evaluation and Research Organization (HERO) derived fatigue factors for the US Army Training and Doctrine Command (TRADOC) (Ref 41). HERO analyzed battles in World War II and the Arab and Israeli wars of 1967 and 1973. The HERO factors apply to division size units when they are in contact with enemy and recovery periods when there is no contact. HERO created three intensity levels measured by percentage of days during a campaign in which the division is in contact with the enemy. The HERO fatigue factors are degradations in abilities to produce casualties. The degradation per day for each intensity level is: 80 percent or more, 7 percent degradation; 50 percent or more but less than 80 percent, 2 percent degradation; less than 50 percent, 1 percent degradation; and during recovery periods, a negative degradation or an increase of 6 percent.

(4) Walter Reed Army Institute of Research (WRAIR), Department of Behavioral Biology, has an ongoing research program on the effects of continuous operations on human performance (Ref 42). The purpose of their research is to develop medical methods for combating the expected degradations. Based on emerging results, WRAIR suggested that 7 percent degradation for all performance per day for combat troops with 5 hours' sleep per night would be a reasonable number to use in this study for demonstration purposes (Ref 43). Since young men tend to need more sleep than older people, with only 5 hours of sleep, the average soldier is operating under a sleep loss condition. Note the similarity with HERO's most intense combat factor.

2-10. `HUMAN PERFORMANCE MEASURES. The horizontal layers (or rows) of the cube were described in the previous paragraphs. Each of the moderators modified the equipment specifications to become increasingly realistic, or combat-like. But what are the data that are modified by the moderator variables? They are the capabilities of the system which are specified by performance measures. Possible performance measures are represented by the columns of the cube (see Figure 2-3).
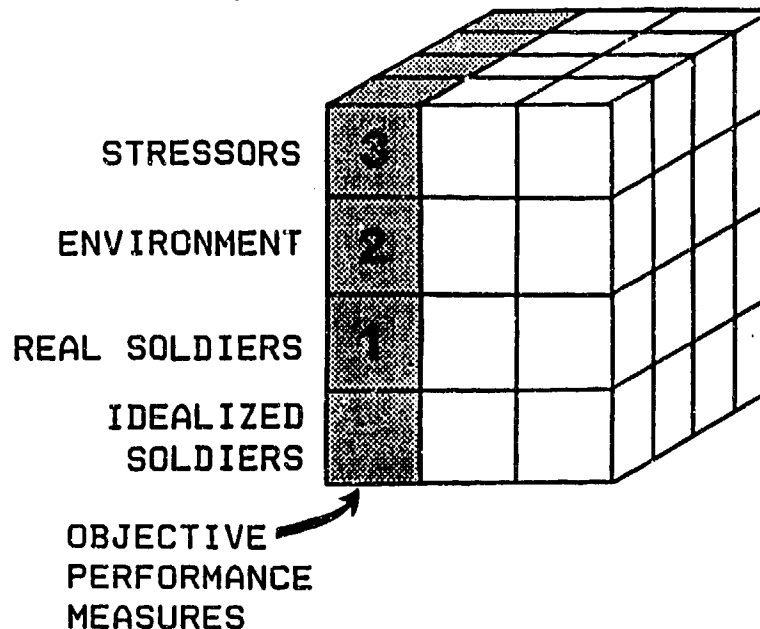
Figure 2-3. Objective Performance Measures

    a. Examples of Objective Performance Measures. The first column in Figure 2-3 represents the least combat-like measures, measures that represent one weapon system operated by one soldier or one crew, in a controlled situation such as training or operational testing. An example using an armor crew might be performance measures collected during a Table VIII exercise (square 1). Table VIII is Army jargon for the tank crew qualification in gunnery test. It is preceded by other tests which work upward in difficulty. If we were to use all Table VIII data for tank performance, we could represent one environmental condition by requesting data for the night test separately from data for day tests. If we also wanted to include weather effects, we would have to ask that the data collection effort include the weather (square 2). If we desired to add the stress of sleep loss, we would want the crews to have lost specified amounts of sleep prior to performing the Table VIII exercises, and the results would belong in square 3.

   b. **Examples of Combat Effectiveness Measures.** The second column,
Figure 2-4, is meant to represent somewhat more combat-like measures than
those in the first column. These are unit effectiveness measures. Taking
our tank crew from the Table VIII exercise and making them part of an armor
platoon performing an Army Training Evaluation Program (ARTEP) exercise
during good weather would create data for square 4. Adding various
environments would allow us to collect data for square 5, and adding
stressors such as sleep loss would move the data into square 6. Collecting
these data and determining the exact numbers for use in combat models will
be more difficult than collecting and analyzing the data in the first
column.
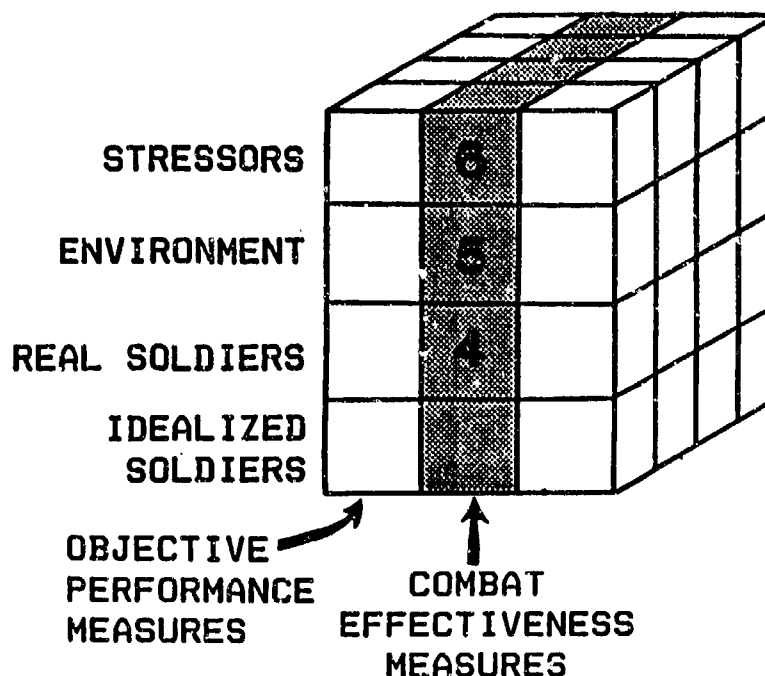
Figure 2-4. Combat Effectiveness Measures

c. **Psychosocial Measures.** The final column, Figure 2-5, represents the addition of individual behaviors and unit variables such as leadership, cohesion and morale which create the psychosocial climate. If we make our platoon one of several in a battalion task force at NTC, the additional problems of communication, decisionmaking, and other unit behaviors become more important. The correct square of the cube is 7, 8, or 9, depending upon the weather and other environmental variables and upon the amount of sleep the crews are allowed.
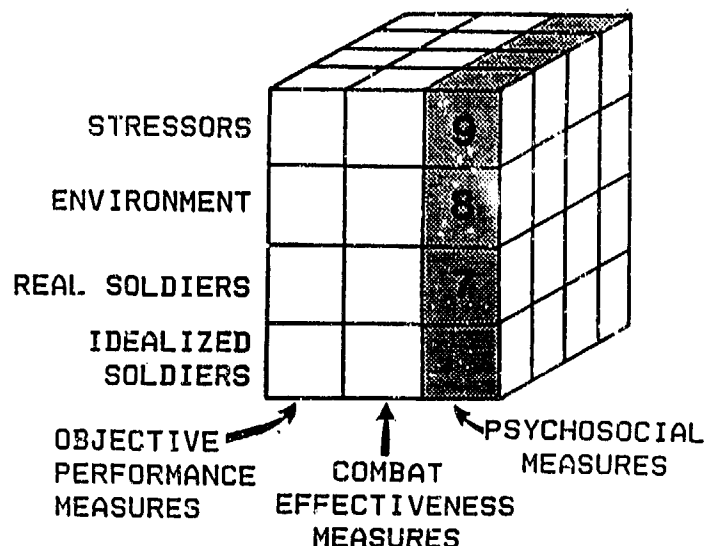
Figure 2-5. Psychosocial Measures

d. **Data Availability.** Table VIII data are appropriate for objective performance (item level) measures for tanks **(Refs 44 and 45)**. Table VIII data have, in the past, been difficult to obtain. However, a computerized data base is in the development phase and should be available soon. A list of parameters is not yet available, but data will be available for day and night tests. Aptitudes or mental categories and date of test will probably be available, and experience levels of the crews may be available. Similar data for other weapon systems have not been located. ARTEP data for use as combat effectiveness measures are less likely to be available than the objective performance measures. Although ARTEP data are collected for evaluation purposes, they are not kept in computerized data bases for statistical analyses across many sets of ARTEP data. If enough data for psychosocial measures were available, we would not necessarily require combat effectiveness measures. However, collecting data for psychosocial measures and determining the amount of variance due to leadership, the amount due to cohesion, etc., will be much more difficult than for either of the previous data types. It is unlikely that all of the required techniques exist. For now, we should not expect to find complete data sets for other than objective performance measures on real soldiers. It may be possible to obtain objective performance data moderated by some of the

major environmental factors and possibly moderated by combat fatigue. If enough NTC data becomes available, it may be possible to use it as a stand-in for psychosocial measures as moderated by combat fatigue and environment. It will be several years before it might be possible to disaggregate NTC data to separate measures such as combat fatigue, leadership, and cohesion.

2-11. **THE THIRD DIMENSION.** The layers of the third dimension represent the differences in individual data from data on very large units, both of which differ from small unit data. Each of these layers is modeled by a different model in the Army model hierarchy. FORCEM models the largest units, with the division being the smallest recognizable unit. The Combined Arms and Support Task Force Evaluation Model (CASTFOREM) models the smallest unit and deals with individual level data. Vector-In-Commander (VIC) will use small unit data to model division battles. The back layer (see Figure 2-6) represents data that may apply to any aggregation level from an individual characteristic such as mental category to a national characteristic such as percent of gross national product spent on military. These factors may have significant effects on the outcome of combat, and should, therefore, have significant effects on the outcome of combat models. However, they are relatively stable factors that do not change signifi-cantly during the time simulated in a combat model (for example, 24 hours for a division-level model or 6 months for a theater-level model). Since their effects would not be expected to change during the simulated time, their effects can be computed without adding any complexity to the combat models. The technique is to first determine the effects that the factor would have on the input data. For example, gross national product per capita might relate to the physical condition of the troops which might affect the number of hours before combat fatigue would greatly affect the majority of the soldiers.
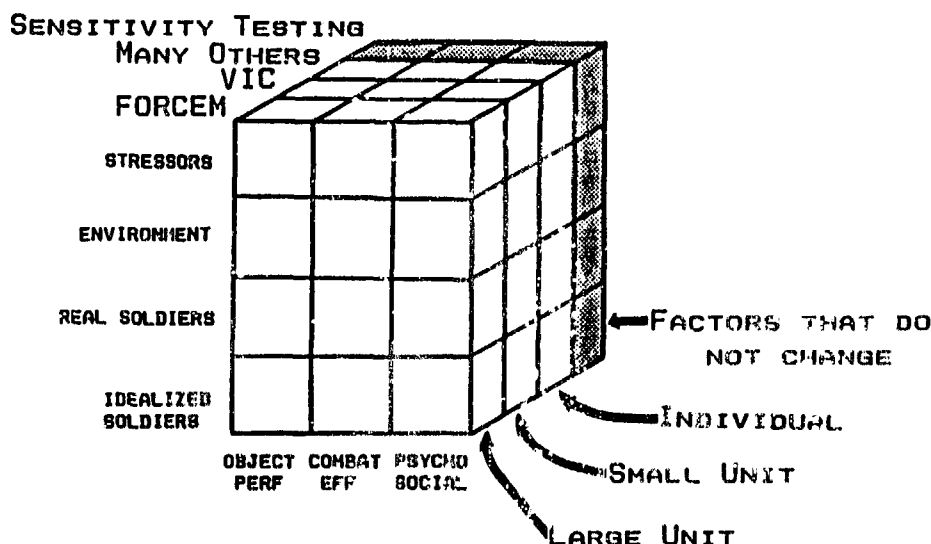
Figure 2-6. The First Dimension

a. **Individual Characteristics.** Much of the research on soldier perfor-
mance has been for the purpose of determining the intellectual requirements
of military jobs. These requirements are used to establish scores on the
Armed Forces Qualification Test (AFQT) that recruits must match in order to
be placed in Army specialties. AFQT results are used to place recruits in
one of six mental categories. Only recruits who place in the highest five
categories (called, from the highest to the lowest accepted, category I,
II, IIIA, IIIB, and IV) are accepted into the Army. Depending upon the
ratio of recruits to Army requirements, a constraint such as "must have
high school diploma" may be placed on recruits in categories IIIB and IV.
In a highly aggregated model, it would only be possible to use data for
average soldiers and it would be necessary to have equivalent performance
data for every weapon played. An example of using mental category in a
combat model is discussed in Chapter 3. The effects of several different
levels of one of these variables could be studied by running the model in a
sensitivity test mode.

b. **National Characteristics.** Researchers at the Army Personnel Research
Establishment (APRE) **(Refs 46, 47, and 48)** in the United Kingdom believe
that there are differences in national characteristics that could be quan-
tified to use in combat models. Although Henderson **(Refs 49 and 50)** writes
about cohesion, his work could be considered to be national characteristics.
He discusses, and attempts to quantify, differences in North Vietnamese,
United States, Soviet and Israeli troops. His measures, however, go from
strong (++) to weak (--); not quantification of the type needed for combat
modeling. HERO has a factor which is called the combat effectiveness value
(CEV). CEV is a measure of the combat troops national differences in any
particular battle. The problem with the CEV is that it cannot be used as a
predictor **(Ref 41)**. However, HERO did create a scale of troop capability
based on the CEV for the Soldier Capability-Army Combat Effectiveness
(SCACE) Study **(Ref 51)**. If this scale could be converted to a quantified
percentage difference in capability, or if Henderson's measures could be
further quantified, national characteristics could be modeled.

2-12. OTHER IMPORTANT FACTORS. The issues discussed here are topics that
seem to be important to actual combat results, and, therefore, should be
considered for inclusion in combat models.

a. **Winter/Summer.** Since heat and a combination of heat and humidity
can cause large performance decrements, it should be modeled. Averaging
winter and summer temperatures to obtain a temperature that is similar to
both spring and fall is very unrealistic. We should consider at least some
sensitivity testing to determine the bounds of what our models would tell
us about summertime and wintertime fighting. (The references for this
topic are included in environment and stress references).

b. "New Guy" Factor and Organizational Concerns

(1) **Research.** Beginning with Sun Tzu (Ref 52) who said, "Generally, management of many is the same as management of few. It is a matter of organization . . . in the tumult and uproar the battle seems chaotic, but there is no disorder . . . order or disorder depends on organization," Army lore seems to require that a war cannot be won without good organization and adherence to the chain of command. Yet, there seems to be no research on the relationship of the organization within Army units to their performance in combat and how performance may change as a result of disorganization during or as a result of combat. One would expect that there should be research directed at recognizing, creating, and maintaining "good" unit organization. Most of the Army organizational research seems to be applicable to the peacetime Army only (Refs 53, 54, 55, and 56). A recent, more oriented to wartime, Navy study (Ref 57) used changes in organizational functioning to forecast unit readiness. It showed that the units which required large numbers of personnel replacements would drop in readiness as compared to other units, while stable units (without many replacements) gained a remarkable amount of readiness, particularly training readiness. Since the effects were lagged, commanders may be blamed for mistakes made by their predecessors or given credit for a previous commander's effectiveness. The report of that study says, "Readiness measures appear to divide up into 'hardware' readiness--equipment and supplies and 'people' readiness--personnel and training. Notably, the overall readiness measure appears to be more closely related to the 'people' readiness measures." If this Navy study can be generalized to the Army combat situation, then the major success predictor is number of replacements required (as a percentage of total numbers). A partial solution is the unit replacement system vice an individual replacement system, but it is not a total solution. Apparently, replacement soldiers (whether replaced as individuals or as a unit) require at least a week to complete an introduction-to-combat phase to learn to adapt to battle conditions, to develop an orientation to friendly and enemy positions, and to adapt to their initial state of constant fear (Ref 29). During the latter half of this period they begin to show signs of again overacting to fear (which seems to leave only about 10 days of the beginning of this 3 weeks which is really the period of maximum effectiveness). In this state they are so fatigued that a period of rest of 48 hours may not relieve their exhaustion.

If not relieved, all men will eventually progress to the point of total incapacitation. This sequence is represented in Figure 2-7. It may be that the combination of new soldiers, soldiers that have been fighting for 8 to 18 days, and soldiers that have been fighting longer than that are the factors that created the 15 to 20 percent who fired their weapon in the battle during World War II, and the higher, but no more than double during Korean battles that Marshall reports (Refs 6, 7 and 13).
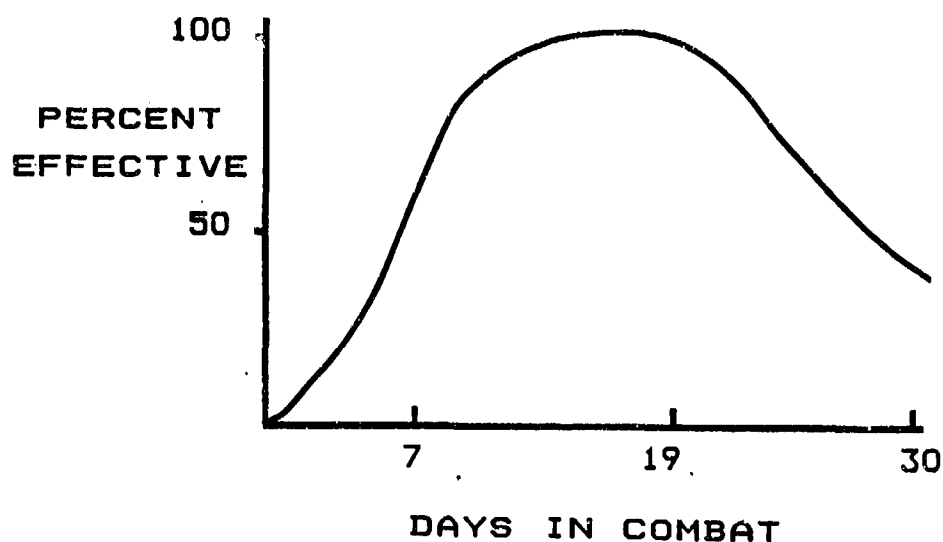
Figure 2-7. The New Guy Factor

(2) **Anecdotal.** Malone (Ref 30) quotes a soldier explaining why experienced soldiers often volunteer to walk as "point man":

> "I used to walk point every day. I wanted to walk point because I hated to put my life in another man's hands. Every organization had a few goof-offs, some guys who weren't quite alert. It's important to remember that there was a big turnover all the time, guys coming in, guys going home, or guys getting killed or wounded, and other guys replacing them. There was no way in **** I'd let a new guy walk point for me. They didn't know what was happening. I didn't want to die for that reason, so I used to walk point. It really scared me to walk point, but I got used to it after a while. You never quite got over that fear . . . the company depended on the point man to keep his head together and get us there."

c. **Suppression.** There are two types of suppression--from fire and virtual. Suppression from fire is that suppression that is created during and for some period of time after enemy fire (sometimes from friendly fire). Virtual suppression is the suppression that occurs because the soldier believes that the enemy may fire, even though there may be no enemy near. The behavior is the same as if the enemy is there and has been firing. Research is ongoing at HEL and Army Development and Evaluation Agency (ADEA) to quantify suppression for use in combat models. CAA should expect to use any data that may result from these projects.

d. **Unit Behaviors, Surprise and C3I.** These topics are grouped for this discussion for several reasons. First, there are little data that are usable in models such as FORCEM and VIC. Second, if the data were available, it is improbable that we have adequate modeling techniques. Finally, all of these contribute to the fog of war and the slow pace at which real wars progress. Most research on unit behaviors such as cohesion, morale or leadership use criteria that are important in the peacetime Army, e.g., attitude towards leaving or staying in the Army. No research was found that might tell us how long a unit of any size needs to regroup and reprepare for battle, or how much time is spent in a static mode versus attack or defend. Surprise is a common subject in anecdotal battle histories, but it is thought to have little relevance for the combat modeling world. No research literature on surprise was found. The converse of surprise is intelligence. How much time is spent on attempting to create deception or surprise, on attempting to get additional intelligence, or on waiting for intelligence reports? The only data available for communications is in terms of time required e.g., bits per second, but one has only to remember the childhood game of telephone to realize that Blue's intelligence about Blue is probably inaccurate. During the battle, how much does Blue really know about where the Red units are, and how much does Red know about Blue? How much of the time do units not realize the other is there when the computer would think they are within line of sight, and therefore, one will attack? The commander may command, but when his intelligence is faulty, how much control does he really have over his units? Certainly no more than he is able to communicate. How often will the communication media work as expected? One thing these topics have in common is that they have a high potential for creating confusion and slowing the pace of war. If we had such data, how would we build it into our combat models? We can treat time, but another thing these topics have in common is that humans are error-prone. It is difficult to determine how to model errors. Can we treat communication errors as probability statements as we do probability of kill? If the orders were to move 10 kilometers and the probability that the unit receives the orders correctly is 50 percent, do we move the unit 5 kilometers? In a deterministic model these decisions can become very difficult to make.

2-13. SUMMARY. This chapter presented the author's interpretation of the applicability to Army combat and to combat models of the literature on human performance. For this purpose, research results were summarized and anecdotes were used to communicate the combat experience. The first paragraphs discussed reasons for including human performance in combat models and why the same factor may have different effects when different doctrine and tactics are used for opposing forces. The next paragraphs discussed the types of parameters that moderate human performance and which would change the models from models of equipment combat to combat (meaning total system) models. Then the types of human or system performance measures that might be obtained were discussed. Estimates of data availabilities were given for the moderators and human performance measures. There is no single source of human performance data that can provide the data needed for combat modeling. A summary statement of data availabilities is, it is probably possible to obtain most of the data that might be needed for models which need data for one soldier or crew, but much of the data that are needed for models of large units are not yet available. However, there are estimates of the effects of the major soldier stressor, combat fatigue. Combat fatigue particularly applies to larger unit models that model many days, or weeks, or months of combat. Since human performance can cause large differences in combat results, techniques for incorporating human data should be developed.

CHAPTER 3

MODEL ANALYSIS RESULTS

3-1. INTRODUCTION. This chapter describes the results of the model analy-
sis portion of the study. The models which were used for this study are
the Force Evaluation Model (FORCEM) and the Vector-In-Commander (VIC) Model.
Both models are two-sided, deterministic, and simulate both land and air
battle. VIC uses information about individual weapon systems to create
information that is aggregated to the battalion level. TRADOC Analysis
Center, White Sands Missile Range (TRAC, WSMR) is creating VIC, and it is
still in the developmental phase. When it is completed, it will be used to
create the kill rates by equipment types that are needed for the FORCEM
battle simulation. FORCEM is the newest theater-level model created by the
US Army Concepts Analysis Agency. Using data from a lower level model, it
creates the combat results for the corps, army, and theater levels. In
addition to the combat simulation, FORCEM simulates the theater support
functions such as maintenance, resupply, and the medical system. Since
FORCEM was created by CAA and is now maintained and updated by CAA, the
major focus of this analysis was on FORCEM.

3-2. GENERAL COMMENTS ABOUT COMBAT MODELS

   a. Human Data Inputs. Models that consider interactions of individual
weapon systems, such as VIC, sometimes have inputs that are specifically
meant to represent system performance, i.e., soldier and equipment perfor-
mance. An example of these inputs is length of time the system suppresses
the enemy after firing, where it is assuming that enemy weapon systems are
suppressed from returning fire because the soldiers are suppressed, not
because the weapon system itself is unable to return fire. Other inputs
may normally be based on equipment design specifications, but could be used
to represent system performance. Examples of these inputs are probability
of detection and probability of hit. However, the operations research ana-
lyst frequently does not know a source for the data required to represent
the weapon and soldier combination. FORCEM is an example of combat models
that simulate the interactions of units rather than individual systems. In
general, these models contain very little human data. The model designer
expects that any human data that may be required will have been in the more
detailed models that are used to generate the inputs. If the amount
included at the lower level is not known and accounted for, adding human
data at this level could result in an incorrect multiplication of human
effects.

   b. **Criteria for Including Data.** The first criterion for deciding that
data should be included in a model should always be whether or not it makes
any significant difference in the outcome of actual combat. If it does
not, then it should not be included in a model of combat. The decision
process for determining whether to include a system characteristic is shown
pictorially in Figure 3-1. Once it is determined that a system character-
istic will make a significant difference, then performance characteristics
of both the equipment and of the soldier must be considered. For example,
assume that the probability of the equipment hitting the target is 95 per-
cent when it is aimed and fired correctly. Then assume that the probability
of a soldier aiming and firing it correctly is 95 percent. Then the proba-
bility of hitting the target when it is fired is only 95 percent of 95 per-
cent, or 90.25 percent for the total system. If either percentage is used
without the other, the hits for that weapon system will be nearly 5 percent
too high.
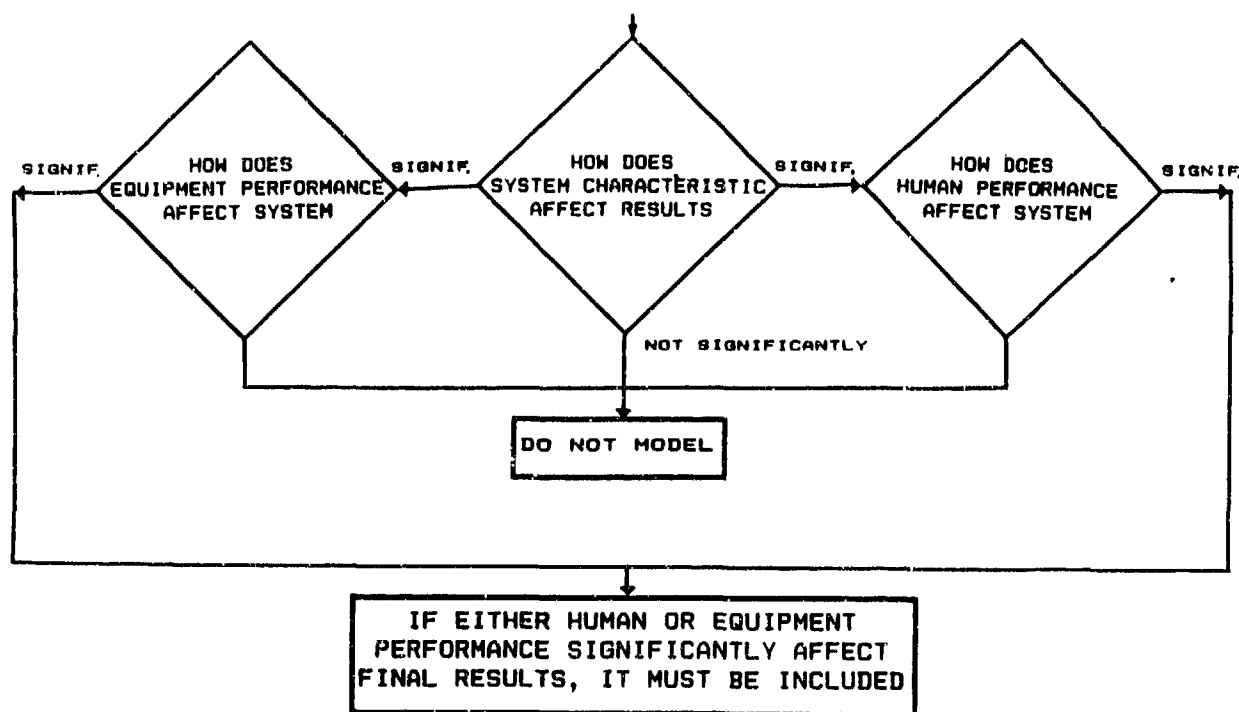
Figure 3-1. Criteria for Including System Characteristics

When all of the other parameters such as probability of target detection
are used, both equipment performance and human performance must be consid-
ered. Similarly, once a system characteristic and either the related
equipment performance, the related human performance, or both are deter-
mined to be significant to combat results (and, therefore, to the model
results), it is necessary to determine whether the performance moderators
should also be included as shown in Figure 3-2.
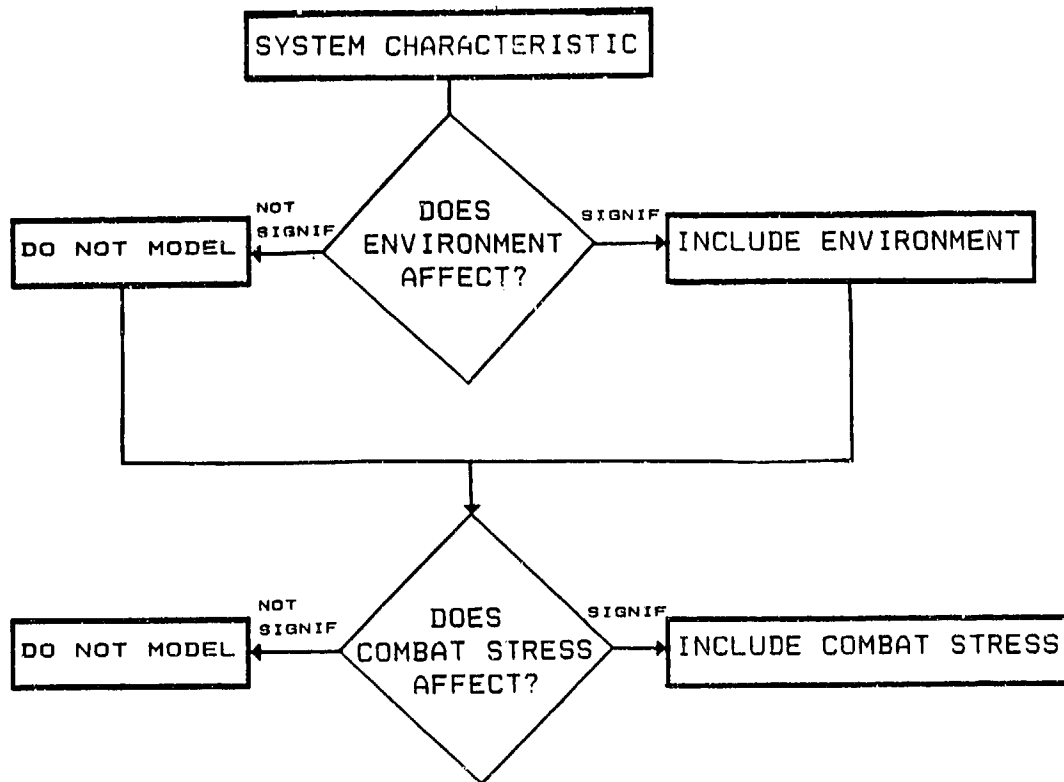
Figure 3-2. Consider Effects of Combat

    c. **Model Decisionmaking.** Analytic models at all levels of detail, such
as FORCEM and VIC, are often designed to run for a specified length of simu-
lated time without the need for interactions with humans. This means that
the decisionmaking process is simulated, and the decisions are only as good
as the program and rules that generate the decisions. The way the rules
(decision tables) will be combined is decided at the time the program is
designed; the rules that determine the decisions are made prior to the model
execution. Therefore, when the same rules are used, whether the decisions
are good or bad, the "commanders" (the model decision program) will always
make the same decisions. It would be difficult to interpret the results of
models that made different decisions each time. The model user, however,
must realize that these models were not designed to simulate actions such
as creativity in the use of forces or outstanding and poor commanders.

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d. **Combat Worth.** Combat worth is a measure of the unit's ability to wage war. It is now used in models to determine such things as enemy/ friendly ratio of combat power and to choose the next unit posture. Combat worth is known by other names, but it is always some aggregation of the ability to create casualties of each of the weapons owned and operable by that unit. If combat models are to represent human factors, then the combat worth should be some function of the capability of the weapons system. In other words, combat worth should be a function of both the equipment capabilities and the capability of the soldiers to operate them at that moment in time.

e. **Breakpoints.** Breakpoints are threshold values, usually based on the number or percentage of casualties that a unit is willing to sustain prior to withdrawing or "breaking" contact with the enemy. It is thought that once the number of casualties reaches this number or percentage, the unit will "break." Nearly all combat models contain breakpoints. No literature located during this study which discussed breakpoint reported any reason for believing that number or percent of casualties had anything whatsoever to do with breaking contact. Authors have looked at other criteria such as one side's casualties related to casualties relative to the other side or rate of casualties over time (**Ref 58**). Again, no evidence can be found that casualties are related in any way. It may be that the final percentage of casualties (which is usually the only number available) is not the relevant number but, instead, the casualties at the time the decision was made. That number may have little relationship to the final number of casualties. In any case, it seems that something other than casualties should be found to use for making the breaking decision--something that has some relationship to fact.

f. **Movement Rates.** Since movement rates are necessary items of information in combat models, better data would be useful. Movement rates are dependent upon differences in terrain. In physics we learn that the same force applied to a very large mass will produce a slower rate of movement than the same force applied to a smaller mass. Similarly, it is probable that there are differences in movement rates among various sized units. These differences are caused by problems such as the amount of communication required and the requirement for all to move at the rate of the slowest unit or vehicle. No movement rate references from the behavioral science community were found. Perhaps NTC data could be used to compare differences between battalion task force rates, company rates and platoon rates. It might then be possible to extrapolate upwards to rates for larger units.

3-4

3-3. FORCEM ANALYSIS

a. **Human Data in FORCEM.** The major use of personnel data in FORCEM is in the computation of unit assets. Unit assets include 4 types of combat personnel (combat crew, dismounted infantrymen, artillery and helicopter crews) and 12 types of support personnel ranging from port personnel to intelligence personnel and drivers. An improvement over the previous theater combat model is that crews for the crew-served weapons are computed from combat crew personnel. If there is not a crew available, equipment that requires crews cannot function. Similarly, convoys for resupply of replacement soldiers and equipment cannot be formed if drivers are not available, etc. However, the soldiers never tire and always work at 100 percent of initial capability, new soldiers arrive in theater at the capability level of 100 percent of the original soldiers' capability, and soldiers always detect targets within range and choose the highest priority target.

b. **The Demonstration System for FORCEM Use of Human Data.** All combat service support functions are based on casualties from the battle, and force commitments and posture determinations are made using results of the battle outcomes. However, the only human representation for the battle module is the calculation of number of crews available. Since the battle module is the major driver for all other FORCEM calculations, it seemed important to demonstrate the effects of adding human parameters or variables to it. The battle module is known as the Attrition Calibration (ATCAL) module. Fortunately, there is a standalone version of ATCAL which was designed specifically for special purpose analyses such as this one. Each execution of ATCAL represents one cycle of FORCEM, or 12 hours of actual combat time, and takes only a few seconds of computer processing time. A special preprocessor which contains a generalized algorithm for personnel performance representation (pergorithm) was created for ATCAL. The pergorithm preprocessor reads the available equipment quantity data, assumes that the correct number of soldiers is available to man the equipment, reads the desired amount of performance degradation, and computes the number of equivalent effective soldiers and crews. Using ATCAL results, the associated changes in results from other modules can be determined. Figure 3-3 is a flow diagram of this process. A separate pass through the process is required for each FORCEM cycle simulated. In the generalized pergorithm processor, a negative degradation represents an increase in performance and is used to represent a variable such as gain in combat experience. The number of weapon systems available is decremented (or incremented for a negative degradation or increase in performance) to represent the number of equivalent effective crews for the shooters. The original number of weapon systems are still available as targets. This allows a gross testing of the pergorithm results without actually making a change to FORCEM.
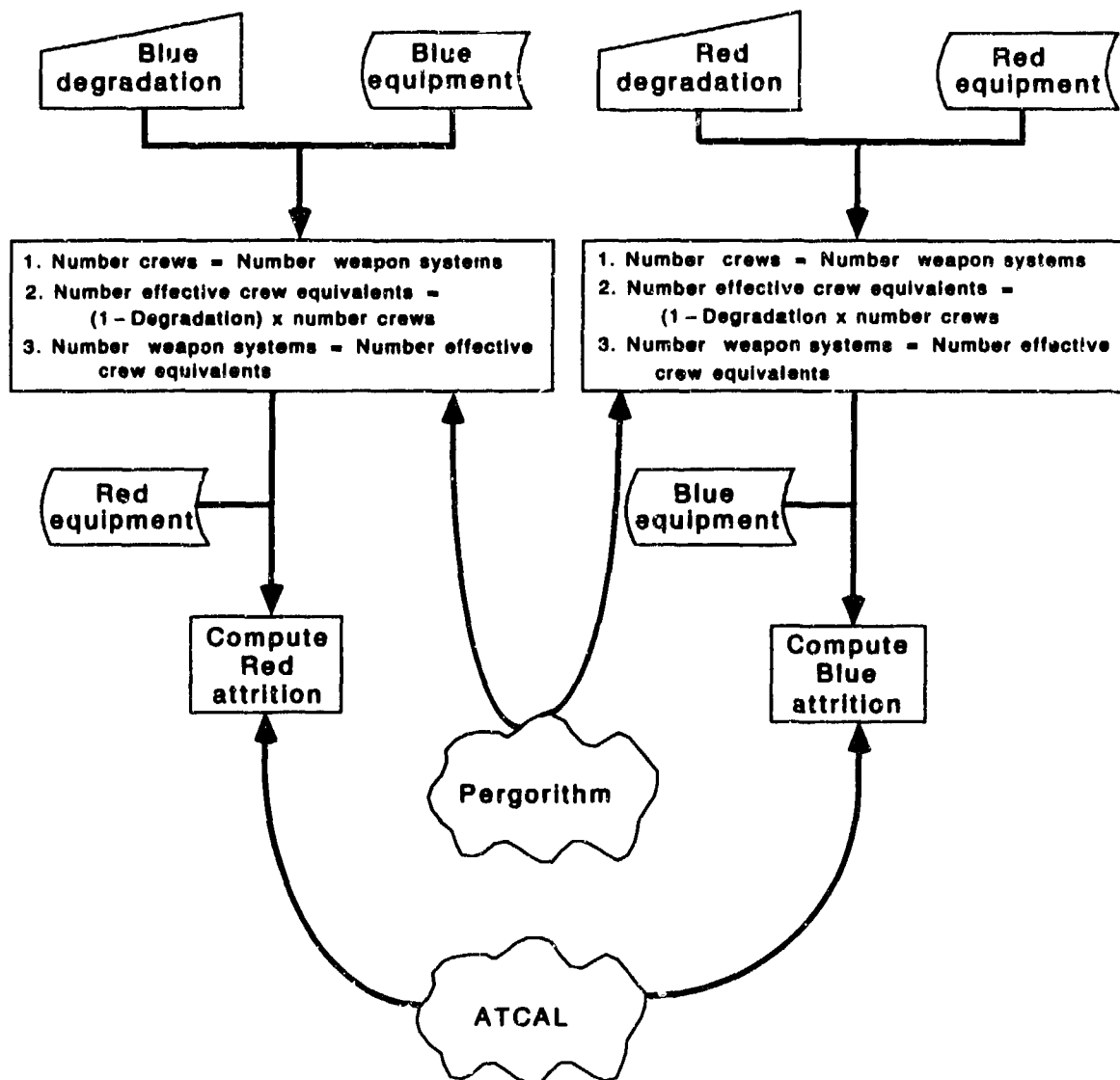
Figure 3-3. The Use of Human Data Demonstration Process

c. **Effect of a Parameter That Does Not Change During Combat.** The degradation factors in this example are the effects of mental categories on expected combat results of soldiers in M60 tanks. A recent article (Ref 59) used Table VIII data to compute the differences in hits obtained by each mental category. Combining information from that article with another report (Ref 60) which claims that soldiers need to be at least mental category II to operate tanks the way our models expect, gives the differences in performance by mental category that are shown in Table 3-1. The reason for the smaller differences shown for the M1 tank versus the M60 tank is the amount of automation in the M1. What the percentage might be without the automation, as could happen in combat, is not yet known.

Table 3-1. Percentage Difference in Tank Equipment Kills
by Mental Category

Type of tank	Gunner and tank commander mental category (percent)				
	I	II	IIA	IIIB	IV
M60	108	100	90	78	61
M1	102	100	97	93	86

To create the data shown in Figure 3-4, five different executions of the pergorithm preprocessor and ATCAL were performed. In each execution, all soldiers are assumed to be the same mental category. The first computed no degradations and the results are shown as mental category II, 100 percent effective. Then, the increase if all soldiers were category I was computed, followed by the degradations for the other mental categories. Since mental category does not change during combat, the method used for this demonstration, preprocessing followed by model execution in a sensitivity mode, is the method of choice. This method saves adding needless complexity to the model. These results are a gross oversimplification, but do show why the Army attempts to recruit better quality soldiers. If it were possible to perform several runs showing the actual mix of soldiers versus several different possible mixes, the Deputy Chief of Staff for Personnel (DCSPER) would have meaningful data for use before Congress. It would not be difficult to develop the necessary pergorithms. The major difficulty is that it would be necessary to find the same data for every weapon system. Results of the type shown in Figure 3-3 would be much more useful than that usually created for the personnel community. If we could provide this type of analytic capability, we in the modeling community would find that our user base would expand rapidly. Actual use of the data should provide additional motivation to the data developers.
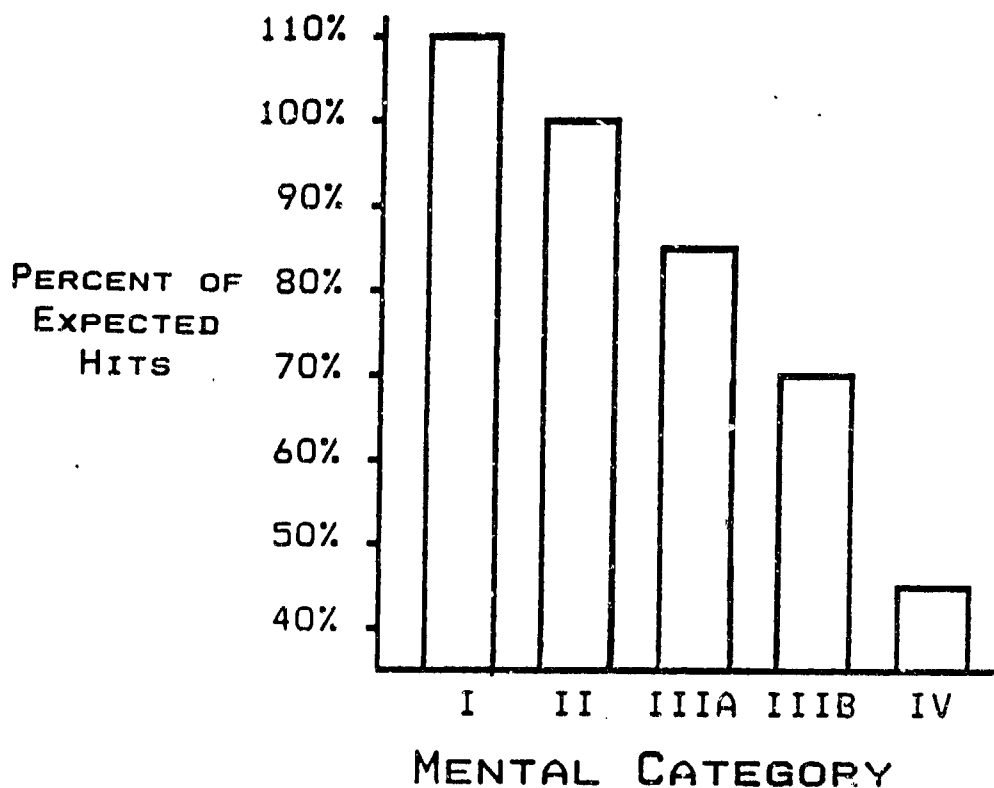
Figure 3-4. Effect of Mental Category on Performance

d. Effects of Two Stress Variables. Soldiers suffer a number of physical and mental stressors during continuous operations. The factor which is expected to cause the most performance degradation is sleep deprivation, where sleep deprivation means any amount of regular sleep which is less than the soldier requires for recovery from all other stressors and environmental effects. FM 22-9 (**Ref 36**) describes the effects of sleep loss on soldier performance and provides a set of charts for mechanized infantry, armor, fire support teams, and artillery duty positions. Although it is the cognitive tasks that degrade most quickly, it is not just the commanders that need to worry about sleep deprivation effects on their planning abilities. When all soldiers lose their initiative and motivation, forget what they should be doing, look at but do not really see the battlefield, have difficulty deciding what to say, how to say it, or what someone else said, the force will be ineffective. The data used in Figure 3-5 are degradation for 24 hours of complete sleep deprivation, followed by continuous operations in which the soldiers received no more than 4 hours of sleep per night.
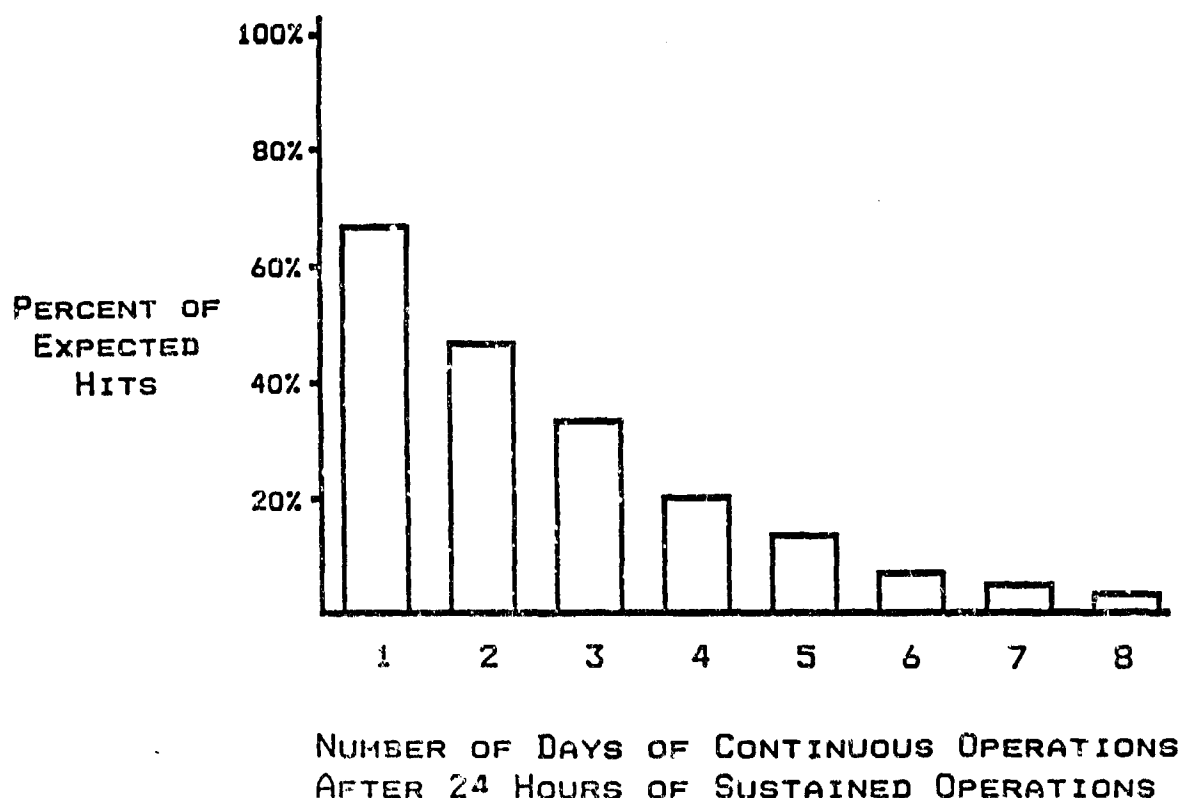
Figure 3-5. Hits During First Model Cycle After 24 Hours of Sustained Operations Followed by Continuous Operations

Again, these are relatively gross estimates because the same factor was used for all soldiers in the battle rather than different factors for each weapon system. However, tne radical drop in expected hits would not disappear when more precise numbers are used in the real pergorithms. There is evidence that the differences may actually be much more than is shown when the more correct pergorithms which change other variables such as rate of fire or probability of hit are used. For comparison, Figure 3-6 shows the continuous operations only (not preceded by sustained operations) when the equivalent effective soldier computation is used.

PERCENT OF EXPECTED HITS

NUMBER OF DAYS OF CONTINUOUS OPERATIONS
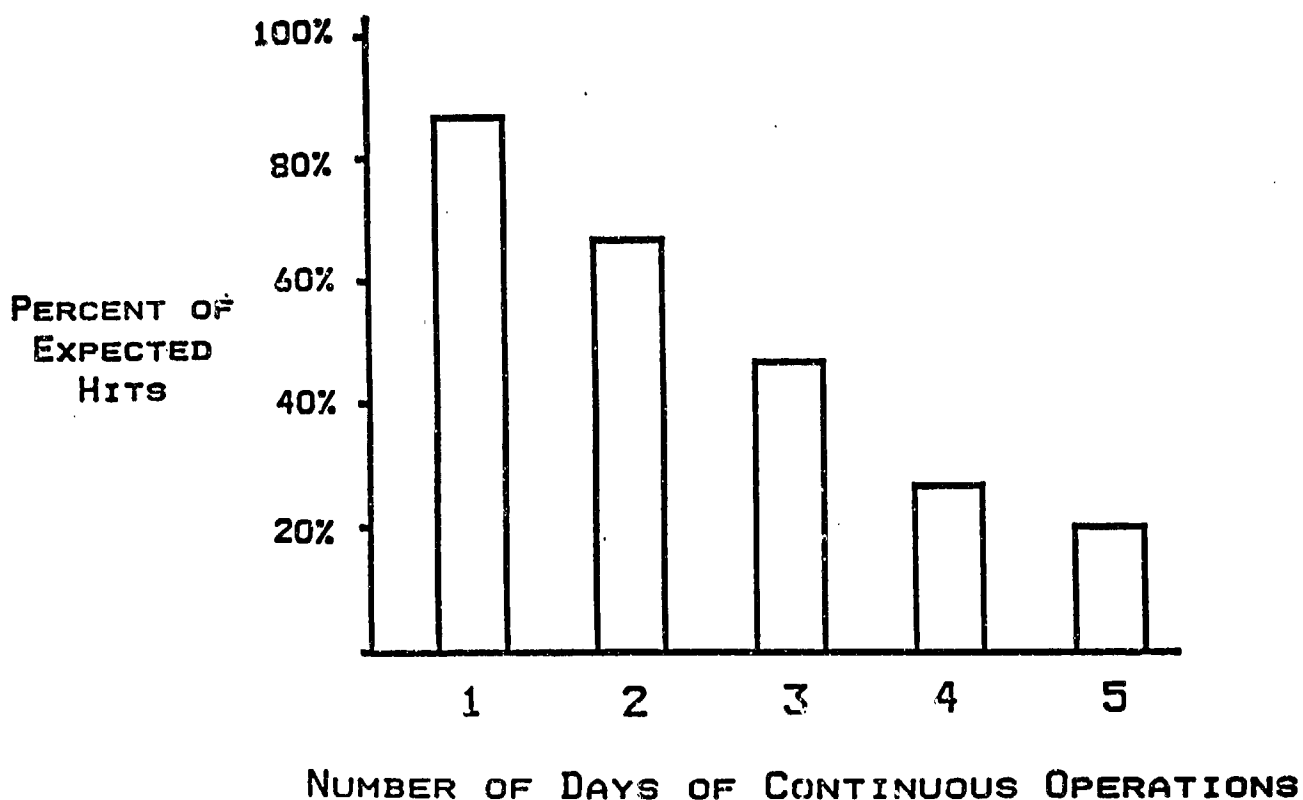
Figure 3-6. Hits During First Model Cycle After 1-5 Days
of Continuous Operations

e. **Estimated Combined Effects of "Real Soldier," Environment, and Stressor Variables.** The final example (Figure 3-7) shows possible combined effects of one variable of each of the three types of moderator variables. In this figure, all soldiers were assumed to be in the average mental category (category IIIA), have been in sustained operations for 24 hours which results in a 25 percent decrement in performance the first day, and 7 hours of the combat were in high heat. Also, the further assumption was made that the effects of all three types of moderators are multiplicative. Since treating the factors as additive would have created a larger performance decrement, multiplicative is the more conservative estimate. Since no data were available, the interactive effects of the variables cannot be estimated. For example, it may be that the stresses of sustained operations or working in high heat might affect soldiers in the higher mental categories differently than those in the lower mental categories.
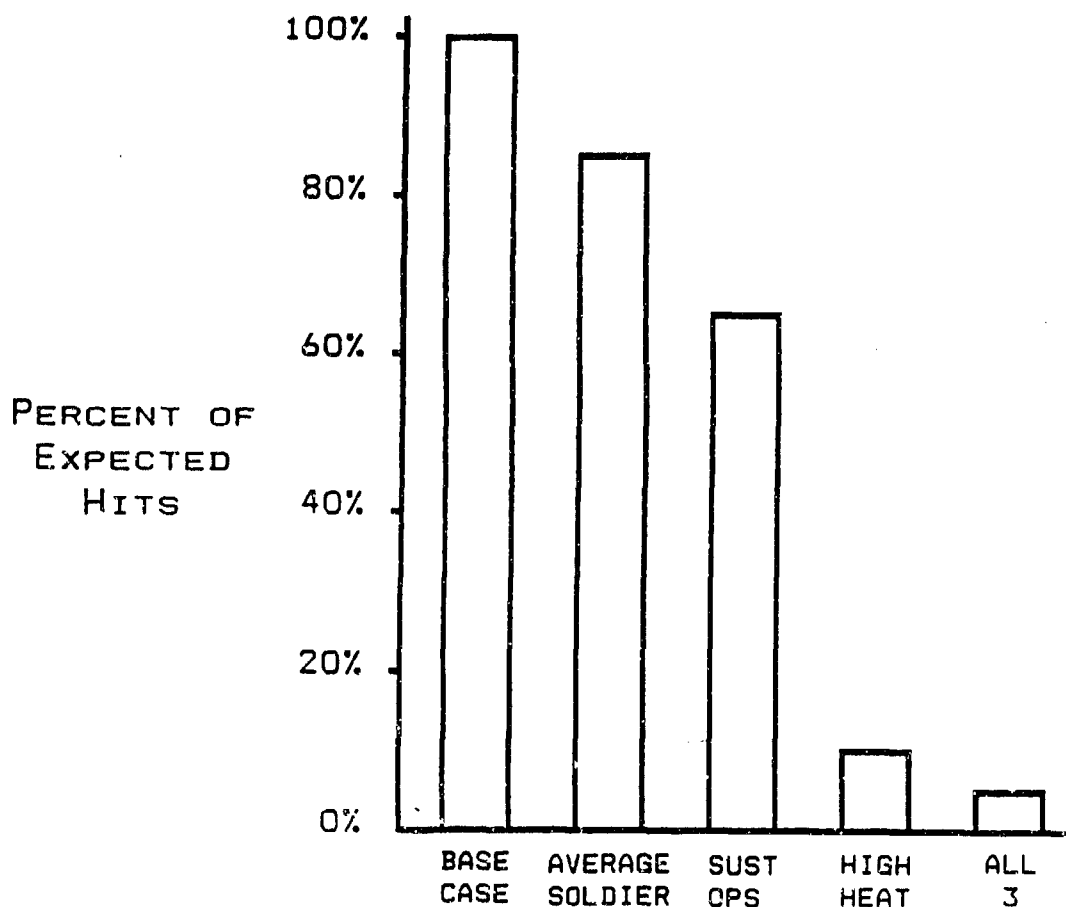
Figure 3-7.   Average Soldiers After 24 Hours of Sustained Operations
with 7 Hours of Excessive Heat

f. **Human Sensitive Factors and Processes in FORCEM Which Need Data.** As had been expected, there are areas in FORCEM which are, or should be, sensitive to human factors, but which are not now well-represented because there is not a known source for the required data or information. For example, FORCEM has both a true data base and a perceived data base. In an actual combat situation, the perceived data base would differ from the true data base in both the timing and the accuracy of information. It is possible to simulate the slowness of communication by slowing the changing of information in the perceived data base from the rate of change in the true data base. However, humans are the communicators and the intelligence gatherers, and humans are error-prone, especially when they are tired or stressed. We do not have the information needed to know what information in the perceived data base should be incorrect, how it should be incorrect, or whether or when it should be changed from incorrect to correct. Nor do we have the information needed to make command and control decisions, such as whether to reinforce and whether to attack or defend, other than by using data elements that can be computed, such as friendly-to-enemy force ratios and unit combat worths (again using true information since we do not know what the perceived information should be). In fact, we now compute combat worth using the value of the equipment assets only--we have not determined how to combine the equipment and personnel performances to compute a system combat worth. Next, there is the breakpoint factor. Finally, we have no way of determining the actions of any unit other than by aggregating the actions of the smaller units which are included in it. The assumption is made that a unit is the sum of its parts, when, in fact, we do not know whether the unit representation should actually be more or less than the sum of its parts. In order to make improvements in theater-level models, the factors involved, values for them and how the factors interact need to be defined for breakpoint, combat worth, command and control, intelligence, and communication. In addition, techniques for aggregating behaviors of individual soldiers and crews to unit behaviors, and techniques for continuing the aggregation to larger and larger size units are needed.

3-4. VIC ANALYSIS

a. **Human Data in VIC.** VIC requires more data elements for describing system capabilities than other models presently used at CAA. Many of these elements are meant to include soldier performance capabilities, e.g., visibility, damage assessment time, heads down time, and a specific degradation for soldier performance which modifies firing rate for munition consumption. For some reason, the degraded firing rate is specifically not used in computing kill rates. Other elements may have been included for representation of the equipment characteristics but could be used to represent the system (i.e., both equipment and soldier) characteristics. For instance, acquisition is a function of visibility, weapon types of firer and target, range, and whether firer and target are moving or stationery. Visibility and moving or stationery are both soldier performance modifiers. If others need to be included, new variables would have to be added or one of these variables would have to be modified to represent it. For example, it might be possible to represent the effect of combat fatigue by multiplying the range by a factor which would make the target further away, thus making the probability of acquisition smaller. Present documentation

3-12

shows that in prior attempts to develop a VIC data base, the analysts frequently used either the value of 0 or 1, depending upon whether it was an additive or multiplicative variable. The value chosen was that which would not modify the final result (i.e., 0 was chosen for an additive variable and 1 was chosen for the multiplicative variables). An example is multiplying the equipment probability of acquisition by 1 for a stationery firer. Or assumptions were made (with no data as a basis for them) about the interactions of variables, such as smoke and distance from target. These assumptions were then used to choose values for decision tables. One reason for using either nondata-based assumptions or a value which would not change the results is that the analysts involved did not know where the needed data could be obtained. Another reason is that the analyst sometimes made the assumption (without having the necessary background information for making it) that the factor would not be important to the results. For all variables which implicitly or explicitly represent soldier capabilities, an extensive data base development is required prior to the first use of VIC. All questions about importance of variables and the appropriate data sources should be determined and documented. This will preclude the necessity for user analysts to continue to subjectively determine the "correct" values for the input parameters. A major question that should be addressed during the data base development is that of whether or not the correct human variables are represented in VIC (as in the example for acquisition above). If variables that could make major differences in the combat results are not included, then recommendations for model changes should be made to the agency that is responsible for VIC update and maintenance (TRAC, WSMR).

b. **Use of VIC by Human Analysts.** Presently, VIC is a difficult model for an analyst to use. It has a different set of inputs for every module, but in many respects the data for each are identical. An example of the duplicity is that the equipment must be specified separately with the name, number played, etc., included in the input data for each module. This requires the analyst to make the same change in many different files every time a change is made to one. Since a data base development effort is required to provide the correct values for the soldier-sensitive parameters, the effort should be expanded to develop one standard VIC data base. The analyst would input each data element to the data base only once. Associated with the data base would be a set of programs that would extract the correct items for each module when it is time to execute VIC.

3-5. **SUMMARY.** This chapter discussed problems with data availability for factors such as breakpoint and movement rates. It then summarized the results of the analysis of the two newest combat models at CAA. This analysis showed that FORCEM could be modified to reflect the detrimental effects of environment and stress on humans. The simulated modification also demonstrated that preprocessing and sensitivity testing could be used to evaluate the effects of soldier characteristics such as mental category that do not change appreciably during the combat period. The FORCEM analysis also revealed areas that need much more information before effective modeling techniques can be devised. The VIC analysis discussed the major human data base development project that should be completed prior to VIC implementation. It also discussed the need to modify the interface between VIC and the analyst to make VIC less cumbersome to use.

CHAPTER 4

COMPARISON OF RESULTS, RECOMMENDATIONS, AND OBSERVATIONS

4-1. INTRODUCTION. This chapter compares the results of the data search and the model analysis and gives examples for each branch of the study decision tree. Additional observations and the recommendations for US Army Concepts Analysis Agency (CAA) management follow the results comparison. An implementation plan for the recommendations is at Appendix G.

4-2. COMPARISON OF RESULTS. The purposes for comparing the results of the two major thrusts of the study were: to determine which human factors can immediately be used in combat models; to delineate the model modifications needed to add human factors to combat models; and to specify areas where additional research is needed. The results comparison allows every human variable that is considered to be placed on one of the branches of the study decision tree, Figure 4-1. In general, variables which belong on the first branch (data exist and models could use now) are variables for which equipment data are usually used, but for which system data could be substituted. Much of these data exist, but they are fragmented among the Army schools and would have to be collected for modeling purposes. Development of a human data base for VIC is recommended for branch 1. The second branch is for data that exist (or for which current efforts should produce usable data), but models do not now contain the appropriate algorithms. As a first step toward implementation, the addition of personnel performance algorithms (pergorithms) to represent combat fatigue in FORCEM is recommended. Continuation could be with temperature effects, then the new guy factor and suppression. A good example of data belonging on branch 3 is mental category. Although differences in soldiers can cause differences in the actual results of combat, soldiers' mental categories do not change during combat. Therefore, the model results should not change during the simulated time as a result of changing mental categories. Adding mental category pergorithms would be a needless complexity, when it can be handled with preprocessing changes and sensitivity testing. (An exception would be a simulation of a very long war when the average mental category of replacement soldiers may be lower than that of the original soldiers.) Branch 4 has variables such as breakpoint which are necessary for nearly every combat model, yet for which there is a dearth of useful data. All variables on this branch seem to point out a great need for additional human research. Variables on the last branch need to be looked at by both model developers and human researchers. These are variables that are not now well modeled because they are not yet well-understood; there are neither data nor appropriate modeling techniques. Variables discussed previously in this report are shown by study branch number in Table 4-1.
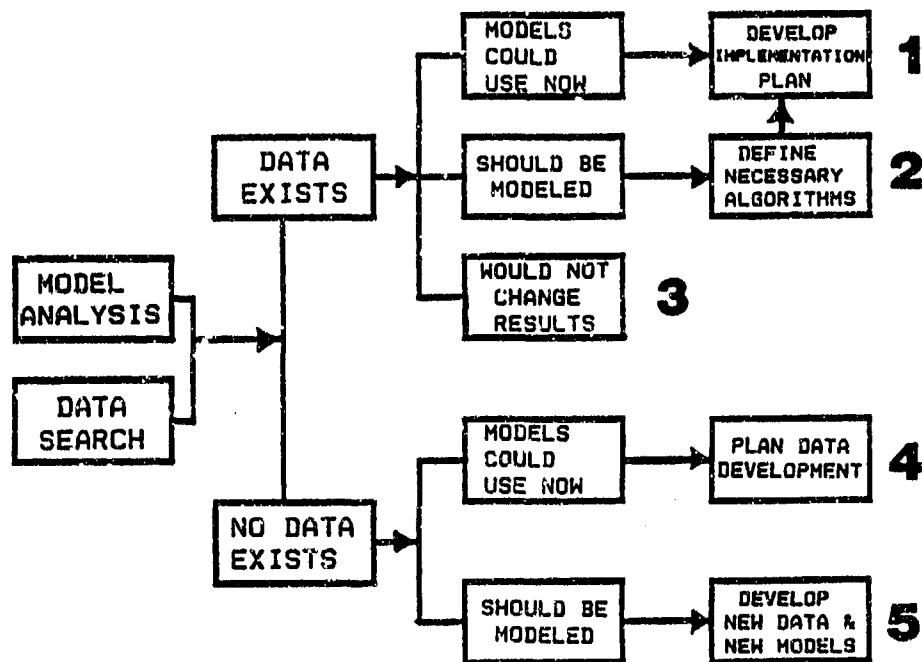
Figure 4-1. Study Decision Tree

Table 4-1. Study Variables by Decision Tree Branch

Some data exist, or will in the near future

1. Some combat models have appropriate pergorithms

Rate of fire
Probability of target detection
Probability of hit
Identification range
Visibility

2. Pergorithms do not exist

Percent who fire
Toxic substance
Combat fatigue
Sleep loss
Heat
Cold
New guy factor
Suppression

3. Will not change results

Few effects expected	Do not change during combat
Humidity	Mental ability
Noise	% GNP to military
Vibration	GNP/capita
Confinement	
Altitude	
Crowding	
Isolation	

No data found

4. Models have requirements for

Combat worth
Breakpoint
Movement rates
Target selection
Posture determination
Damage assessment time

5. Pergorithms do not exist

Fear
Deprivation (e.g., food, water)
Communication
Courage
Morale
Cohesion
National differences in:
  Resistance to disease
  Willingness to fight
  Training levels
  Leadership
Surprise
Intelligence
Command and control
Decisionmaking
Aggregation techniques

4-3. RECOMMENDATIONS. Based on the results, a set of recommendations for improving the use of human data in the two combat models, VIC and FORCEM, are presented in this paragraph. A recommendation to improve the ability of humans to input data to the VIC Model is included. Table 4-2 provides a summary of the recommendations. The implementation plan for these recommendations is presented in Appendix G.

Table 4-2.   Recommendations

Action	FORCEM	VIC

Introduce pergorithms for:
    Combat fatigue
    Personnel availability
	X
	X	

Develop human performance data base		X
Improve analyst interface		X
Evaluate presence/absence of human parameters		X
Develop priority list for additional pergorithms	X	

For values that do not change,
    use preprocessing and
        sensitivity testing
	X	X

   a. **Modify Models Only for Variables Which Change.** Modifications should not be made to division-level models (VIC) or theater-level models (FORCEM) to represent human factors that do not change during combat, e.g., educational level. If the Army is interested in the results in combat of changing a human factor such as the soldiers' average mental ability, either of these models could be used for that purpose by changing the input via the preprocessing programs rather than by making changes to the models.

   b. **FORCEM Modification.** Personnel performance algorithms (pergorithms) should be phased into FORCEM. They should always be designed such that the user may choose to run FORCEM with or without pergorithms. The pergorithm that should be developed first is the one that is most likely to make differences in combat results and which cannot be represented in FORCEM by introducing it to a lower level model and allowing the results to "sift up" to FORCEM. Since the lower level models do not usually simulate more than a few hours of combat, combat fatigue is the most likely candidate. An

associated parameter that must be used in conjunction is the assumption for number of hours' sleep that will be allowed once the unit is committed to combat.

c. VIC Data Base

(1) If VIC results are to be meaningful, the data base for human-sensitive parameters should be developed prior to the first actual use in a study. Otherwise, it will be necessary for individual analysts to choose input values based on limited knowledge of appropriate ranges.

(2) The file structure and information required for input to VIC is complex and very difficult for analysts to use. Important points made in discussions of systems, versus equipment and people, are that equipment should be used for those purposes at which it excels, and that people capabilities should always be considered when designing the equipment. These should be applied to human (civilian and military operations research analysts) use of the VIC Model. Suggestions for improvement are included in the implementation plan in Appendix G.

4-4. OBSERVATIONS. The following observations are thoughts developed by the author during the course of this study. Although references are not given for most of them, they are not entirely random thoughts. However, the reader should not necessarily expect to find that other authors have synthesized available material in the same way.

a. In general, human factors are discussed in this report as if they are all negative. The reason is that the point of departure in present model assumptions is "human performance is perfect." The only direction for performance to go from perfect is down. In other words, if a unit is filled with rested, perfectly trained soldiers who are in perfect physical condition, who have been battle conditioned, who have the best leaders and the highest levels of morale, cohesion, esprit de corps, and willingness to fight, then that unit's performance might be close to the level expected by most of the CAA models. As soon as the combat begins, the soldiers must begin to tire. The initial performance decrement from tiredness will be overcome by their bodies' natural "fight or flight" hormone production. However, within a relatively short period of time, the next normal physical response is that the body's depleted capability to respond to stress must cause performance decrements which no amount of leadership, training, or other external factor, even fear for life, can overcome.

b. Although command and control is frequently referred to as a force multiplier, the difficulties involved with communication during combat could mean that the requirement for communication in order to coordinate the actions of many crews may actually cause command, control and communication to have no effect or to be a "force divisor."

c. When a change to represent a human factor is made for one side, e.g., Blue, the same change must be made for the other side. Sometimes, the difference in doctrine may mean that more than one change may be necessary

in order to not penalize one side unfairly. For example, if the Red doctrine is that units will rapidly be replaced with new units who have not been previously in battle, then the "new guy" factor may be more relevant for Red than a fatigue factor. Nevertheless, the fatigue factor should be applied to both sides. If procedures used to get soldiers to the front require sleep loss, then the performance should be decremented for the number of days enroute. A different combination of hours of sleep and fatigue factor should normally be input for each side.

d. Very little research has been performed during actual combat. Because the intense feeling of fear for life cannot be duplicated in a research environment, it is probably impossible to completely replicate combat conditions for research purposes. The Operations Research Office of Johns Hopkins University took physical measurements from three groups of infantrymen in Korea in 1952 (Ref 33). One group was in intense combat for 18 hours and suffered 61 percent casualties. A second group was in less intense combat for 5 days; its casualties were 17 percent during that period. The third group was not committed to combat, was called upon for frequent patrols, and was subjected to heavy artillery fire. Measurements that ORO felt were most valuable were "those which gave an indication of the activity of the adrenal gland and its effects on body metabolism." These data could be used to validate whether subjects have been sufficiently stressed during contemporary research.

e. Presently, when we do not know where to obtain the values needed for soldier-sensitive data, we ask a soldier (military operations research analyst or point of contact in another organization) to provide a value that seems right. There have been several research projects which specifically looked at the probability that a value created by judgment is a correct value. Some have found that experts cannot make correct judgments (Ref 61). Others state that judgment is the only way to get good data on an area such as effects of combat fatigue (Ref 62), and some have tried to measure judges' accuracy and found good results (Ref 63). Although the Delphi method of obtaining judgment data was developed by the Rand Corporation, a later evaluation by Rand determined that the Delphi technique has never been validated and frequently the experts that were surveyed are not happy with the results obtained by this method (Ref 64). It would seem that the objective of a model data base development effort should always be to obtain empirical data rather than judgmental data. The individual analyst should never be required to determine the correct value.

f. Presently, the types of analysis performed at CAA are perceived by the personnel community as being useful for making hardware-type decisions, not for people decisions. How many tanks do we need, how much ammunition, how should equipment be allocated among units? But wars are fought by people not by equipment. How realistic are decisions based on equipment parameters only? And, why should we not answer some of the difficult personnel questions that personnel people have learned not to ask of us? Questions such as: Will the amount of sleep we allow really make any difference in the outcome of the war? Would we be better off not to be nice guys, and instead force our soldiers to work longer and harder? Or

would we really be better off to insist that they sleep more than we are now planning? Can we get by by having them catnap as much as possible, but allowing fewer hours' sleep? What happens when we cut short the amount of training before we ship them overseas? Is the total war effort better served by training them more or by getting them in better physical condition? How much is it worth to acclimatize soldiers before sending them to the battle zone? The medical people can project the result in terms of the individual soldier, but our theater-level models are the appropriate level to answer questions about the total war effort.

g. Time limitations precluded providing more than a cursory overview of the voluminous literature on subjects such as stress. The references provided for each topic in Appendix D should provide the interested reader with most of the desired detail. Additional useful references can be obtained from the bibliographies of the references provided. The bibliography of this report provides additional, but perhaps less directly useful references than those in Appendix D.

h. The modeling community should continuously watch for new methods for representing combat. Catastrophe theory is an example of a relatively new technique that may someday be useful. When first contemplating a possible connection with combat modeling, it seemed that catastrophe theory might very well be the best method for dealing with breakpoint. Within one set of data it can show or explain both the phenomena of a sudden break with the enemy, and the seemingly very different phenomena of a very slow change from active combat to no contact. Further contemplation brought the realization that it might be used to represent the entire combat process. Modelers who are used to controlling thousands of detailed parameters may violently disagree with the catastrophe theory requirement that there be only four controlling parameters. However, think of four parameters which represent available firepower, status of personnel in terms of both numbers and fighting capability, logistic support and a national factor which represents several global variables such as the political climate. Perhaps, particularly at the theater level, no other parameters are needed to determine whether the war is won or lost and whether it happens quickly or takes many months or years. Using catastrophe theory and the FORCEM data bases (both input and output), it might be possible to develop a very quick running model for making multiple excursions.

4-5. SOME NOTES ON RELATED EFFORTS. Two recent efforts were reviewed which had goals similar to this project. Since they seem to come to opposite conclusions, each are briefly described.

a. An English analyst, D. Rowland, compared combat history data to data from firing ranges and field experiments for rifles and machineguns in defensive operations in small units (**Ref 65**). For rifles, he found that the degradation from firing range performance to field experiment performance is a factor of 10. The further degradation from field experiment to actual combat is another factor of 10. The machinegun performance did not degrade quite so radically; the proportion was about 100:15 versus 100:10

for riflemen. This means that out of 1,000 targets hit in the firing range tests, the riflemen would hit only 10 in combat; the machineguns would hit 25. This finding seems to correlate with recent findings from NTC (Ref 5).

b. An effort to test the use of human data in CASTFOREM resulted in no difference in outcomes (Ref 65). The reason for this was the choice of variable tested. Subjects were tested on acquiring a target in a test facility where they knew there would be a target. The time it took for them to go through the firing sequence after they made the decision to fire was measured. The analyst then averaged the times for the 50 percent who fired most quickly, and separately averaged the times of the slower 50 percent. These averages were 9 seconds and 11 seconds. When CASTFOREM was tested using these times to fire, the outcomes were the same. The study conclusion was that soldier variables were not important. Yet the analyst did not measure the time to acquire the target (the time it takes to see something, to identify it, and to decide to fire). As long as the task is within the physical capabilities of all personnel tested, there are usually greater differences among humans in the cognitive aspects of tasks than in the physical, frequently practiced and learned-by-rote aspects. Another essential data element collected, but apparently not used, was the accuracy of target identification--40 percent of the time the test subjects were not firing at a hostile target. In other words, only 60 percent of the kills were kills of enemy; the other 40 percent were kills of friendly troops.

4-6. SUMMARY. This chapter compared the results of the two major phases of the ME = f(PER) Study and presented the study recommendations. The recommendations are based on the results of the data search, the model analysis and the results comparison. A set of observations which were developed during the study, but which were not specifically related to the objectives or the study plan, was presented. Finally, two efforts with goals similar to this project were discussed.

CHAPTER 5

SUMMARY

5-1. INTRODUCTION. The purpose of this chapter is to briefly summarize the study report. The results of each of the two major, concurrent approaches are summarized, followed by a summary of the recommendations. The recommendations are based on a comparison of the two sets of results.

5-2. DATA SEARCH. The literature on combat shows that human behavior and performance have made a significant contribution to the results of actual combat. Research literature shows that humans are probably less reliable, and may require more maintenance than the equipment they use. Models of combat that do not include human data as well as equipment data will be extremely unrealistic. There is no extant data base on human performance that is suitable for use in combat models. Since the data on human performance is collected for purposes other than modeling (e.g., operational testing and training evaluation), it is fragmented among various testing agencies and Army schools.

5-3. MODEL ANALYSIS. The model analysis concentrated on the two newest CAA combat models. The first is the Force Evaluation Model (FORCEM). FORCEM is a two-sided, deterministic theater model developed by CAA. Of necessity, it is highly aggregated. The other is a more detailed, two-sided, deterministic combat model--the Vector-In-Commander (VIC) Model. VIC will be used to develop the killer victim scoreboards that are needed as input to FORCEM.

    a. FORCEM Analysis. Very little human data is used in FORCEM. Apparently, the model designers expected that required performance data would be represented in the data output from the detailed models which is used as FORCEM input. With some of the assumptions that are frequently made about the next war, e.g., the requirement for continuous and sustained operations, additional human performance variables should be included. A demonstration system, which was composed of a standalone personnel performance algorithm (pergorithm) program and a standalone version of the FORCEM battle module, was used to represent the effects of using human data in FORCEM. Mental category, heat and combat fatigue were the variables used in this demonstration.

    b. VIC Analysis. Many more human performance variables are included in VIC than in FORCEM. There may be more data required than can be located at the present time. VIC has not yet been analyzed in sufficient detail to assure that the most relevant factors are the ones that are included. During the analysis of the input data requirements, redundant input requirements were noted. In its present form, VIC is a difficult model to use.

5-4. RECOMMENDATIONS

a. General Recommendations. Rather than adding model complexity by putting code in the model, variables that do not change during the combat time simulated should be modeled by a combination of preprocessing and sensitivity testing. This does not apply to variables for which doctrine and tactics cause differing effects to the two sides. Also, variables should not be added to combat models unless they are known to affect combat results or the ability to support the combat.

b. FORCEM Recommendations. Many human performance characteristics should have been accounted for in the models which create FORCEM input data. However, some characteristics may be more applicable to the theater level or to a model which covers a long span of time. These should be built into FORCEM. There is now some data available for effects of combat fatigue and more is expected in the future. As a proof of concept, combat fatigue and the associated parameter of hours of sleep allowed should be the first variables included. As more data become available on topics such as communication, command and control, intelligence, and unit aggregation techniques, FORCEM should be improved to accommodate them.

c. VIC Recommendations. Three types of improvements are recommended for VIC: a human performance data base should be developed so that analysts know where to locate the required data; variables included in VIC and not included in VIC should be compared to determine whether the most important are those that are now in VIC; and the interface for the user analyst should be improved.

5-5. SUMMARY. Although all the data required are not yet available, there are some, particularly in the areas of actual soldier capabilities and combat fatigue. Combat fatigue should be one of the variables in FORCEM; hours of sleep is a required input parameter. A data base of actual soldier capabilities should be developed for use with VIC, the analyst interface with VIC should be improved, and more analysis is needed to determine whether the correct variables are in VIC.

APPENDIX A

STUDY CONTRIBUTORS

1. STUDY TEAM

a. Study Director

Ms Sally J. Van Nostrand, Force Systems Directorate

b. External Member

Dr. Irving Alderman, US Army Research Institute for the Behavioral and Social Sciences.

2. PRODUCT REVIEW BOARD

a. Internal Members

LTC John S. Smith, Chairman
Ms Rosie H. Brown
Ms Adele P. Narva
Mr. Kenneth R. Simmons
Ms Tanya Peltz

b. External Member

Dr. Franklin Moses, US Army Research Institute for the Behavioral and Social Sciences.

APPENDIX B

STUDY PROPOSAL

CSCA-FSP   8 JULY 1985

APPLICATION FOR CAA RESEARCH AND STUDY FELLOWSHIP

SALLY J. VAN NOSTRAND

1. PROJECT PURPOSE. Although human participation and influence are pervasive in land combat, manpower and personnel issues and effects of human factors or human performance (MP/HFP) are considered only implicitly in force-on-force models. The purpose of this research is to identify those areas in which the modeling of battlefield processes could be modified to include manpower and personnel computations and the effects of human factors and human performance.

2. OBJECTIVES.

   a. Identify the combat model processes, inputs, or phenomena which are potentially most sensitive to the effects of manpower, personnel and human factors or human performance.

   b. Determine data base elements and process algorithms which will permit appropriate modifications of the processes.

   c. Define and verify additional algorithms and data, or changes to existing algorithms and data that would be necessary to generate the MP/HFP functions to be included in the processes.

3. PRODUCTS. The final report will include an implementation plan for making the required modifications to FORCEM and VIC, including changed or additional algorithms and data elements.

4. REFERENCES.

   a. Miller, George J. and Bonder, Seth, Human Factors Representations for Combat Models, Technical Report 571, US Army Research Institute for the Behavioral and Social Sciences, July 1982.

   b. Siegel, Arthur I., Pfeiffer, Mark G., Kopstein, Felix F., Wilson, Lawrence G., and Ozkaptan, Halim, Human Performance in Continuous Operations: Volume I, Human Performance Guidelines, Research Product 80-a. US Army Research Institute for the Behavioral and Social Sciences, December, 1979.

5. APPROACH.

   a. Evaluate existing human factor and human performance data to determine the applicability in land combat models.

   b. Perform a top-down analysis of the FORCEM and VIC Models, including their interface to determine appropriate inclusion points for human factors or human performance and to determine feasibility of additional computations to provide new manpower and personnel information such as replacement by specialty or career management field in final model results.

c. Develop new or changed algorithms and data elements as needed.

d. Document the changes and include in the final report.

6. VALUE TO CAA AND ARMY. Incorporation of results of this research in the most important Army combat models will expand the scope of analysis issues which can be addressed in CAA studies and provide results which are more accurate and sensitive to important human characteristics and interactions as well as manpower availability. Proper use of model results in Army decisionmaking should effect better decisions in areas such as force structuring, system procurement, recruiting and training. The other immediate benefit to CAA, and perhaps eventually, to other analytic agencies is a concrete demonstration of the value of personnel research and study.

7. VALUE TO SELF DEVELOPMENT. Study of the most important Army combat models and designing their expanded logics will provide me with a broader subject matter expertise and allow me to exercise my creativity in an area that is generally of more importance than manpower and personnel to CAA and the majority of the Army.

8. TIME SCHEDULE. Six months allocated as follows:

a. Month one through three will combine evaluation of human factor and performance data and analysis of FORCEM and VIC.

b. Development of algorithms and data elements will be during the months four and five.

c. Although documentation will be performed throughout the project, the final form including the implementation plan will be prepared during the final month.

9. SUPPORT REQUIREMENTS.

a. Model documentations for FORCEM and VIC to include listings of model code.

b. Access to the Sperry computer for exercising the PERFECT Model (obtained from ARI).

c. Access to a PC for new algorithm development.

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APPENDIX C

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APPENDIX D

LITERATURE ORDERED BY TOPIC

D-1. INTRODUCTION. The purpose of this appendix is to provide a list of useful papers and books in addition to those specifically referenced. Those that are in the bibliography but not referenced in the text nor listed here seemed to have less direct relevance. References are provided only for publications actually read, not for those listed in other bibliographies but not actually obtained. They are categorized using the topics that are discussed in this report. Since many references could fit into two or more categories, they are listed under the topic to which they most contributed to the author's understanding. In this appendix, the topics are listed in the same order they are addressed in the body of the report. The first topic is real soldiers from Chapter 2. The last is catastrophe theory from Chapter 4. These are followed by a set of references which are related to combat models but not necessarily to human factors or effects.

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*Denotes reports which are administrative in nature rather than reporting of results.

APPENDIX F

QUANTIFICATION OF EFFECTS OF COMBAT FATIGUE

F-1. INTRODUCTION. Since quantification of combat fatigue is a widely recognized need, there have been several attempts to quantify the effects for training or modeling purposes. The purpose of this appendix is to provide a more complete description of the quantification efforts that are briefly mentioned in Chapter 2, paragraph 2-9, Stress Variables.

F-2. FIELD MANUAL 26-2, THE MANAGEMENT OF STRESS IN ARMY OPERATIONS. FM 26-2 (Ref 67) is a summary of detrimental effects of several types of stress. One caution, however, is that one glance at the figures or not reading the prose can be very misleading. For example, a figure on page 14 of FM 26-2 shows that soldiers can perform physical tasks (physical tasks include loading rifles and field stripping weapons) for 3 days with no sleep. The next bullet in the figure explains that ALL soldiers became stress casualties by the 4th day. The same figure shows that 91 percent of soldiers remained effective on performance of physical tasks for 9 days on only 3 hours of sleep per night. The FM had earlier explained, "tired muscles can be made to work (although less well) for a short period of time, no matter how tired one becomes." The FM does not explain how much "less well" the physical task performance could have been performed and still have been considered to be effective after those 9 days. However, the FM also explains that the brain cannot function as well with insufficient sleep. Performance on mental tasks such as detecting presence of enemy, identification of a potential target as friend or foe, understanding and following orders, and displaying initiative or motivation deteriorate rapidly under sleep deprivation or other physical and mental stresses. Soldiers begin to make fatal errors in decisions, having hallucinations and may become unable to make life and death decisions. In fact, this FM states that casualties from combat stress alone are expected to be at least one to every four combat casualties "in war characterized by continuous operations on a high-intensity integrated battlefield." In other words, although the figures in this FM can lead one to believe that soldiers can function with no or very little sleep for long periods of time, commanders must realize that after sleep deprivation their soldiers will be functioning on the physical level only; they will not be performing their total job adequately. In this state they can be a danger to themselves and to the rest of the unit.

F-3. FIELD MANUAL 22-9, SOLDIER PERFORMANCE IN CONTINUOUS OPERATIONS.
FM 22-9 (Ref 36) describes the types of performance decrements that should
be expected during continuous operations, work/rest schedules, approximate
recovery times required, and contains several charts that show performance
decrements by job within specialties. Table F-1 shows some approximate
performance decrements taken from the charts. These charts should be useful
in models that are at a job-level resolution. This FM states that the data
for the charts were created using a "mathematical technique" but does not
say what that technique is. The mathematical technique is the PERFECT com-
puter model which is briefly described in the next paragraph.

Table F-1. Approximate Performance Decrements from FM 22-9

Unit/Duty position	Percent in 5 days	Five-day unit average	Per day unit average
Mechanized infantry		74	15
Maneuver team member	50		
*Gunner/carrier team leader	67		
*Mech infantry platoon leader	71		
*Mech infantry squad leader	85		
Armor		44	9
Tank loader	3		
Tank gunner	13		
*Tank commander	36		
*Tank platoon leader	52		
Fire support		54	11
*Fire support NCO	12		
Radio/telephone operator	23		
*FIST chief	72		
*Forward observer	78		
Artillery		62	12
155 Crew member	16		
*Howitzer section chief	56		
155 Gunner	61		
*Battery executive officer	68		

*Critical duty position

F-4. PERFORMANCE EFFECTIVENESS OF COMBAT TROOPS (PERFECT) MODEL. PERFECT is a model of a small unit in continuous operations developed for ARI. It is based on research reviewed during a program titled "Human Performance in Continuous Operations." The primary output is the data which represents sets of curves showing the degradation over time of each soldier's performance. The following description of PERFECT was taken from the User's Manual **(Ref 40)**:

"PERFECT was developed to aid in the understanding of human performance during night and continuous operations. The model was designed as a means of assessing the cumulative effect of many stress-producing variables on human performance during continuous combat. In addition, the model allows insight on the potential interaction between variables which affect combat performance...The model simulates degradation of combat effectiveness and stress buildup of ground combat troops during continuous operations. This model permits analysis of anticipated performance effectiveness when variables such as continuous time in battle, light level, enemy/friendly numerical ratio, enemy/friendly terrain advantage, amount of platooning, and amount of sleep permitted are varied alone or in combination. The model uses effectiveness values derived from previous ARI research to yield estimates of performance indices and stress values. These estimates are given by type of unit, by composition of unit, by initial proficiency level of unit, by performance factor, by total operation of all units and by enemy/friendly strength ratios."

F-5. HISTORICAL RESEARCH AND EVALUATION ORGANIZATION (HERO). In some research for the Training and Doctrine Command (TRADOC), HERO evaluated data from battles in both World War II and the Israeli and Arab wars of 1967 and 1973 **(Ref 41)**. The HERO fatigue factor for division-sized units engaged in intensive combat is very similar to the performance degradations predicted by the PERFECT Model and printed in FM 22-9, and to the overall performance degradation factor suggested by the Department of Behavioral Biology, Walter Reed Army Institute of Research **(Ref 43)**. The following extract is from the conclusion section of the study report:

> "The effectiveness of military formations, from division through corps to field army, can be measured in terms of Fatigue Indicators, which reflect a combination of performance criteria, of which the most important seem to be the ability to inflict casualties and the intensity of combat...for larger formations, such as corps or armies, in extended campaign operations, the decline in performance can be represented by a gradually increasing Fatigue Factor with a decline of about 1.65% per day at the outset of the campaign, up to a maximum decline of about 2.70% per day by the 25th day...for the divisions participating in such campaigns, the daily decline in performance is about 6.79% per day during brief periods of intensive combat; it is about 1.94% per day for longer periods in which the divisions are actively engaged less than 80% of the time; it is about 1.39% for periods in which the divisions are engaged 50% or less of the time...during lulls, or periods in which divisions are not committed to active combat, they recover previously lost combat effectiveness (as manifested in Fatigue Indicators) at a rate of about 5.94% per day."

F-6. **COMPARISON.** The performance degradations predicted by the PERFECT Model and printed in FM 22-9 are larger than the degradation factors computed from historical data. The reason for the discrepancy has not been analyzed in detail. However, the author believes that the difference is probably due to the difference in the size of unit considered. The PERFECT Model expects that a small unit (platoon) will be in enemy contact throughout the period simulated. Since the historical analysis was concerned with division-size units, it is unlikely that all platoons would be in contact every day. Therefore, although individual platoons may have developed performance degradations of sizes equivalent to those in Table F-1, the overall division performance, averaged across many platoons, would have had a smaller decrement.

F-7. **SUMMARY.** This appendix discussed the differences in physical and mental task performances when the soldier is fatigued. In general, physical tasks show less degradation for a longer period of time. Mental tasks show two types of degradation. The first is nonperformance. With no sleep, soldiers will not be able to continue more than 3 days. The other error type is in decisionmaking and perception which can cause the soldier to make fatal errors. Table F-1 showed performance degradations computed by the PERFECT Model and published in FM 22-9. These degradations are based on laboratory results of human performance research. Then a study effort by HERO for TRADOC was described. This study used historical data from World War II and the Israeli and Arab wars of 1967 and 1973. The fatigue factors developed by this study show a 7 percent decrement per day in ability to cause casualties during intense combat and a recovery factor of 6 percent per day when not committed to combat. Although the factors computed by the PERFECT Model are much larger than the 7 percent computed by HERO, the difference is probably caused by the difference in size of unit considered.

APPENDIX G

IMPLEMENTATION PLAN

G-1. INTRODUCTION. This implementation plan is the Phase 1 plan for completing the work required to implement the recommendations that resulted from the Model Effectiveness as a Function of Personnel (ME = f(PER)) Study. There are four sections. After a section of definitions, there is a section which is the plan for making the first modifications to the Force Evaluation Model (FORCEM). The third section is the plan for creating the data base that will be needed for running the Vector-In-Commander (VIC) Model. The final section contains suggestions for continuing the two efforts.

G-2. DEFINITIONS

a. Human Factor - data or variables having to do with human performance or the human as a part of a system.

b. Pergorithm - personnel performance algorithm; pergorithms should be kept distinct from equipment algorithms and model modifications should be designed so that pergorithms can be turned off or on by the setting of one input data switch.

c. Available Personnel - the number of people who are not resting (sleeping, eating, or in transit to and from a rest area).

G-3. FORCEM

a. The first pergorithm which should be added to FORCEM is for combat fatigue.

b. Input parameters (a separate set for each side) needed for the combat fatigue pergorithm are:

(1) Hours of Rest - an input assumption for number of hours of sleep that each soldier will be given.

(2) Hours Unavailable - the number of hours that each soldier will be unavailable for duty; this number should be equal to or larger than the value given for hours of rest; when it equals hours of rest, the soldier is expected to sleep in place and the rest will be less reviving than if removed to a rest area; if greater than hours of rest, the soldier is removed to a rest area and the difference is the time required for the soldier to travel to and from the area.

(3) Daily Performance Percent Decrement - this decrement is based on a combination of hours of rest and whether the rest was in place or in a rest area; for ease of computation, 1/2 of this percentage can be computed for each 12-hour cycle (1/4 for 6-hour cycle, etc.).

c. The decrement in performance should be applied for every day that the unit is in continuous operations. Although this may normally be units that are in contact with the enemy, travel days that cause sleep deprivation must be included. If combat service support units are expected to be operating in a continuous operations mode, their performance must also be decremented. If the sponsor wants to apply different assumptions about hours of sleep to combat units than are applied to other units, then a separate set of data will be required for each.

d. Performance is decremented for combat units by applying the daily performance percent decrement to the ability to cause casualties. The standalone version of the battle module, ATCAL, can be used to test the best method of decrementing casualties. The simplest method would be to compute casualties normally. Then, before returning to the main program, decrement the casualties. The method of choice is probably that which causes the least increase in execution time, so casualty decrement should be tested against decrements to the main inputs to phase 2. These inputs are quantity of vehicles, rate, range, availability and Pk (actually, probability of hit, not probability of kill).

e. Performance is decremented in noncombat units by applying the daily performance percent decrement to the work performed by that unit. For example, the number of maintenance hours required to repair a tank could be increased by the amount of the performance decrement and the number of trucks loaded for convoy could be decreased by the performance decrement.

f. Available personnel must be computed by removing the proportion of soldiers that must be unavailable for work using the hours unavailable parameter. In other words, if each soldier were allowed 6 hours of sleep in place, then during continuous operations 1/4 of the soldiers would be unavailable at all times; if they were allowed only 4 hours of sleep, but they travel 1 hour each direction to the rest area, then 1/4 of the soldiers are unavailable at all times.

G-4. VECTOR-IN-COMMANDER (VIC). Before examining VIC for additional human parameters and creating the need for modifications to the VIC design, it is necessary to assure that a data source has been identified for all of the data that is already required as input, that the data has been acquired, and that it is in a usable format. This process has two distinct steps as shown in Figure G-1. The first step is to explicitly use soldier data by accumulating the human data used by VIC; the other is to improve the human use of VIC.

- **EXPLICITLY USE SOLDIER DATA**
    - IDENTIFY SOLDIER-SENSITIVE INPUTS
    - DETERMINE BEST DATA SOURCES, AND
        NECESSARY TRANSFORMS
    - <u>DOCUMENT</u> DATA SOURCES & TRANSFORMS
    - BUILD INITIAL SOLDIER DATA BASE

- **IMPROVE DATA INPUT PROCESS FOR HUMANS**
    - DETERMINE FILE INTERRELATIONSHIPS
    - BUILD AUTOMATIC UPDATING PROCEDURE
    - <u>DOCUMENT</u> DATA SOURCES & PROCEDURES
    - BUILD DATA BASE

Figure G-1. Prepare for Vector-In-Commander (VIC)

   a. Explicitly Use Soldier Data. The method presently used for setting values in parameters that an analyst feels are probably sensitive to the soldier performance is very subjective. At a data conference, points of contact are asked for their opinion on what the value should be. The analyst then devises some method for combining these and inputs a value. The purpose of this task is to develop a set of soldier-sensitive data inputs that are as standard and as well documented as the equipment data that is obtained from sources such as AMSAA. The steps involved are described below, paragraph G-4c, steps 1 through 6.

   b. Improve Data Input Process for Humans. VIC is a modular model that is so modular that it requires a complete set of data to be created and input for each module. Unfortunately, many of these data are repeated for each module (example--number of weapon systems and name of each), and the instructions for creating the data inputs frequently warn "the analyst must assure that variable x in this module must be the same value as variable y in another module." This makes it very difficult for the analyst to create the input data, and does not take advantage of one of the main strengths of a computer (which is also a weakness in people). That computer strength is the ability to perform the same data manipulations over and over again,

exactly the same way each time. This strength can be used by creating one data base which has all information needed, but present only once. This is the data base with which the analyst works. Once the data has been completely created (and it is possible to create much additional aid for this part, too), there should be a set of preprocessing programs which access the data base and create all of the multiple input files that are required for VIC. Steps required for this task are described in the next paragraph, steps 4 through 6.

    c. **VIC Data Base Development Plan.** All of the following steps are necessary to explicitly use soldier data; steps 4 through 6 include both explicit use of soldier data and improve data input process for humans. The steps, with estimated professional staff months (PSM) and calendar months are summarized in Figure G-2.

	PSM	MON #
● CATALOG HUMAN FACTOR DATA REQUIREMENTS (CATALOG INCLUDES DOCUMENT)	3	1-2
● IDENTIFY DATA SOURCES, DEVELOP TRANSFORMS, AND DOCUMENT	12	2-8
● DEVELOP TECHNIQUES FOR ACQUIRING UNAVAILABLE DATA AND DOCUMENT	6	5-10
● DEVELOP ANALYST-DATABASE MANAGEMENT INTERFACE (PRE-PREPROCESSOR) AND DOCUMENT	12	2-15
● DEVELOP SCENARIOS FOR TESTING INPUTS AND DOCUMENT	6	4-6
● EVALUATE AND DOCUMENT INPUT EFFECTS (ITERATIVE PROCESS); INCLUDES SENSITIVITY TESTING	21	7-15
TOTAL	60	

Figure G-2. VIC Data Base Development Plan

G-4

(1) **Catalog Human Factor Data Requirements.** Every VIC input must be scrutinized to determine whether the value should be dependent upon soldier capabilities. The determination must be made by a military subject matter expert, by an analyst familiar with human research, or (preferably) a team made up of one of each. Every determination must be documented in an understandable and retrievable format. During this task, documentation should begin for data that should affect combat results but which are not called for by VIC. This process should be continued throughout the following tasks.

(2) **Identify Data Sources, Develop Transforms, and Document.** For every input which was determined to be dependent upon soldier capability, a data source must be identified, samples obtained for format verification, necessary transforms developed, and documented. Examples of possible data sources include the Army schools, ADEA, BRL, CDEC, NTC and OTEA. The documentation of this step must be sufficient so that a different analyst in a later year can feel comfortable with the process, and either use the data in the data base or, if necessary, follow the same process to obtain updated data. It will not be possible to obtain all required data immediately. For that which is unobtainable, documentation must show the requirement to include the following step. For data that is available, the following step is skipped.

(3) **Develop Techniques for Acquiring Unavailable Data and Document.** For all data that is presently unavailable, a specific procedure for creating the required values is required. It should never be left to the analyst to "make a good guess" (research on results of judgmental data shows that a value based on a good guess may be worse than using a random number generator). Preferably, this task should be performed by a psychologist with questionnaire and research design expertise.

(4) **Develop Analyst-Database Management Interface (Pre-preprocessor) and Document.** This task requires a computer-oriented analyst who understands the requirements for developing an easy-to-use database, who will document the design and the procedure for using it. The database resulting from this task will contain all of the VIC input data, both the soldier-sensitive parameters and all of the other data required to execute VIC. In addition to the database, programs that will create the required input files from the database at execution time must be designed and programed.

(5) **Develop Scenarios for Testing Inputs and Document.** The purpose of scenarios developed in this task is to create VIC executions that are simple and straightforward. An analyst should be able to easily understand the reasons for results obtained. For example, to track whether a change made in target detection data is making the desired changes in the model execution, it may not be necessary to activate all other modules, e.g., artillery may be extraneous for checking target detection data for tanks. Scenarios developed in this task should be documented to the extent necessary to reuse them whenever new data is obtained to test it for reasonableness.

(6) **Evaluate and Document Input Effects.** This is an iterative testing process of all of the VIC input data, with special emphasis on the soldier-sensitive data. During this process, data elements will be identified that do not vary enough to affect the model results; the documentation from steps 1 through 3 for these data should be modified to reflect this knowledge. The model may prove particularly sensitive to other data. In this case, the values supplied are critical and extreme care should be taken in collecting and entering these data. Again, the earlier documentation should be modified to reflect this new knowledge. By the conclusion of this task, the documentation should be completed of missing soldier-sensitive data which was started in task 1. These data should be evaluated in terms of their expected effect on model results. If the outcome would be measurably different, VIC modifications should be considered. Personnel needed for this task should include the computer person from task 5 and the military analyst, psychologist, and other analysts from previous tasks.

G-5. PHASE TWO AND BEYOND. During the past 2 years, all levels of Army management have placed more emphasis on consideration of the soldier as part of the total system. This interest should rapidly propagate the availability of better soldier data. The VIC soldier database and the FORCEM Model should both be considered evolving entities that CAA plans to continually improve. When data from sources such as NTC are incorporated in VIC with the results used for FORCEM killer/victim boards, the pace of battle may be radically slower. Some data (e.g., effects of heat on soldier performance) are available now that is not usable by either model. Whether the final effect will be to speed or slow the pace of battle is not positively known, but, since models now seem to assume perfect human behavior, the fog of war that is so often written about may be seen to actually be the soldier performance. Humans may have an amazing ability to store and connect assorted information needed for decisionmaking, but they also frequently behave in a confused, contradictory and slow manner.

APPENDIX H

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GLOSSARY

1. ABBREVIATIONS, ACRONYMS, AND SHORT TERMS

ADEA   Army Development and Evaluation Agency

AFIT   Air Force Institute of Technology

AFQT   Armed Forces Qualification Test

AMSAA   US Army Materiel Systems Analysis Agency

ARI   US Army Research Institute for the Behavioral and
            Social Sciences

ARTEP   Army Training and Evaluation Program

BRL   US Army Ballistics Research Laboratory

c^3I command, control, communications, and intelligence

CAA   US Army Concepts Analysis Agency

CDEC   US Army Combat Developments Experimentation Command

DA   Department of the Army

DARPA   Defense Advanced Research Projects Agency

DCSPER   Deputy Chief of Staff for Personnel

DIA   Defense Intelligence Agency

DNA   Defense Nuclear Agency

DNBI   disease and nonbattle injuries

DOD   Department of Defense

DS   direct support

DTIC   Defense Technical Information Center

FIST   fire support team

FM   field manual

GNP   gross national product

GS   general support

HEL	US Army Human Engineering Laboratory
HERO	Historical Evaluation and Research Organization
hrs	hours
HumRRO	Human Resources Research Organization
IDA	Institute for Defense Analysis
K-kill	catastrophic kill
MANPRINT	manpower and personnel integration
max	maximum
MICOM	US Army Missile Command
mo/MON	month(s)
NASA	National Aeronautics and Space Administration
NBC	nuclear, biological, chemical
NPGS	Naval Post Graduate School
NTC	National Training Center
NUSC	Naval Underwater Systems Center
ONR	Office of Naval Research
ORO	Operations Research Office, John Hopkins University
OTEA	Operational Test and Evaluation Agency
POL	petroleum, oils, and lubricants
PRB	Product Review Board
RD&A	research, development, and acquisition
TRAC-FL	TRADOC Analysis Center - Fort Leavenworth
TRAC-WSMR	TRADOC Analysis Center - White Sands Missle Range
TRADOC	US Army Training and Doctrine Command
TRASANA	US Army TRADOC Systems Analysis Activity
US	United States

USAPFI   US Army Physical Fitness Institute

USAREC   US Army Recruiting Command

USARIEM   US Army Research Institute for Environmental Medicine

USASSC   US Army Soldier Support Center

WIA   wounded in action

WRAIR   Walter Reed Army Institute of Research

2. TERMS UNIQUE TO THIS STUDY

eff   effectiveness

M1   M1 tank

M60   M60 tank

P   probability

perf   performance

pergorithm   personnel performance algorithm

signif   significant

sust   sustained

sys ops   system operations

Table VIII   the eighth in a series of tank gunnery tests

3. MODELS, ROUTINES, AND SIMULATIONS

ATCAL   Attrition Calibration - generates simulated combat
                attrition results, suitable for use in a theater-level
                simulation

CASTFOREM   Combined Arms and Support Task Force Evaluation Model

COSAGE   Combat Sample Generator - a two-sided, stochastic,
                high-resolution (division-level) simulation model which
                simulates a day's combat activity to generate
                ammunition consumption and equipment and personnel loss
                data

FORCEM   Force Evaluation Model - a two-sided, deterministic
representation of land and air combat and support
operations for an extended theater campaign

PERFECT   Performance Effectiveness of Combat Troops - a computer
model combines task analyses of Army jobs with results
from human laboratory research on topics such as sleep
loss, noise, visual activity, and reasoning abilities
to compute performance over time for each soldier is a
small unit during combat operations.

VIC   Vector-In-Commander Model - a two-sided, deterministic
representation of land and air combat for battalion-
size units

4. DEFINITIONS

combat fatigue
The fatigue that develops in all soldiers when they are in combat or
performing supporting work in combat conditions. It is the result of
the many different stresses, both of the physiological type, such as
sleep loss and of the psychological type, such as fear.

continuous operations
The unit performs its function 24 hours a day with no discernible dif-
ference based on the time of day or night. Each soldier is expected to
get some minimum amount of sleep, but sleep is in shifts so that work
or combat does not stop.

individual characteristics
Characteristics of the soldier which will make a significant difference
in his ability to fight or perform supporting tasks but that do not
change during the battle. Intelligence is an example. In aggregated
models such as those used at CAA, individual characteristics can be
modeled in a sensitivity mode.

mental category
All recruits into the military services are given paper and pencil
tests which are used to determine their ability to perform the various
military jobs. The categories are labeled I, II, IIIA, IIIB, IV, and
V. The highest mental category is Category I, a soldier in this
category can learn to do any job. The lowest mental category soldier
that the Army accepts is Category IV; a soldier in this category can
learn some jobs but will not be able to learn to perform the jobs that
require highly technical and difficult-to-learn skills.

moderators
Conditions of the battle (or work environment for support personnel)
which can significantly affect the results. Modeling moderators may
require changes to model code.

national characteristics
> Characteristics that, in general, apply to all soldiers on the Blue side or to all soldiers on the Red side, but not to both and which make a significant difference in their fighting ability. Effects of these can usually be studied with sensitivity tests.

new guy factor
> Research has found that soldiers cannot be completely effective when they are first in combat. They seem to need about a week to reach their peak performance. This is referred to in this report as the new guy factor.

stressors
> Stressors are a subset of moderators which are difficult to measure, but are important to model because their effect on the human can cause radical decrements in the soldiers' performance.

sustained operations
> The unit performs its function 24 hours a day as in continuous operations; however, no soldier is given time to rest or sleep. The unit will be nearly zero percent effective at the end of 3 days of sustained operations.

	MODEL EFFECTIVENESS AS A FUNCTION OF PERSONNEL [ME = f(PER)]	STUDY SUMMARY
CAA		CAA-SR-86-34

THE REASON FOR PERFORMING THIS STUDY is to identify those areas in which the modeling of battlefield processes in the US Army Concepts Analysis Agency (CAA) could and should be modified to include the effects of human factors or human performance.

THE PRINCIPAL ACCOMPLISHMENTS of the work reported here are:

(1) This research determined that humans make large differences in real-world combat results. Therefore, human data should make similar differences in the results of models of combat. A modification of the Force Evaluation Model (FORCEM) which reflects the detrimental effects of environment and stress on humans was created. This modification was used to demonstrate model results that could be expected when human data are represented.

(2) It was determined that the human performance data that are available were collected for other purposes (e.g., for operational testing or for training evaluation) and that these data must be obtained from multiple sources. A complete set of all data that might be useful for modeling purposes cannot be generated from extant data. However, the physical and psychological limits of human performance indicate that the results of combat are as likely to be determined by human performance under stress, such as that generated by continuous operations, as by differences in equipment capabilities. Therefore, there is an urgent need for additional human performance data.

(3) This project demonstrated that preprocessing and sensitivity testing could be used to evaluate the effects of soldier characteristics, such as mental category, that do not change appreciably during the combat period.

(4) The results of this project include a list of human data that should be included in combat models, an implementation plan for this list, and another list of important variables that may need more study before they can be incorporated.

(5) An additional benefit from this research is the development of a common vocabulary for use of human data in combat models. This vocabulary will be used for communication between the modeling community and the human research community.

THE KEY ASSUMPTIONS

(1) Enough verifiable data exist which can be used as a basis for testing the concept of modeling human performance in combat.

(2) Algorithms can be developed to model human factors.

(3) These algorithms can be adapted to the CAA combat models.

THE PRINCIPAL LIMITATION is that resources available for this study do not permit making and testing modifications to model code or developing a human factor data base.

THE STUDY OBJECTIVES are to:

(1) Identify the combat processes which are potentially most sensitive to the effects of human factors or human performance.

(2) Determine existing data base elements and process algorithms which will permit appropriate modifications of the models of combat processes by simple changes to the data base.

(3) Define and verify new algorithms and data that are necessary to generate the additional human factor functions that should be included in the combat model processes.

THE BASIC APPROACH is that both a search for human data relevant to combat results and a model analysis of appropriate points for inclusion of human data are used. The model analysis is not constrained by whether data are already available for use, nor is the search for data limited to that which would be immediately usable in the model.

THE STUDY EFFORT was performed by Ms Sally J. Van Nostrand under the CAA Research and Study Fellowship Program.

COMMENTS AND QUESTIONS may be addressed to the Director, US Army Concepts Analysis Agency, ATTN: CSCA-FSP, 8120 Woodmont Avenue, Bethesda, MD 20814-2797.